MULTI OBJECTIVE DECISION ANALYSIS FOR ASSIGNMENT PROBLEMS

THESIS

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Abstract

One of the most common problems in Operations Research is the assignment problem. It deals with the optimization of a decision makers' goal by matching objects in one group (jobs) with objects in another (machines). Flight scheduling in fighter squadrons is a hard and complicated problem which comes with a dynamic environment and multiple decision makers and goals. Using pilots as machines and missions to be flown as jobs, the fighter squadron flight scheduling problem can be solved like an assignment problem with multiple goals. This research develops a new way to solve the multi-objective assignment problem and demonstrates this new approach using the fighter squadron flight scheduling problem as an example.

In this research, the Value Focused Thinking method is applied to build a decision analysis model to help decision makers in fighter squadrons evaluate the mission-pilot matches. The decision model built with the help of experienced schedulers is used not only for evaluating matches but also for ordering assignments to see priorities. To verify and validate this model, ten groups of alternatives were randomly created and evaluated by the model and the decision maker. The results from this analysis show that the decision model is valid and proved to be helpful and accelerated the assignment matching process.

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To My Late Father

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

MULTI OBJECTIVE DECISION ANALYSIS FOR ASSIGNMENT PROBLEMS

1. INTRODUCTION

1.1 General Problem

In all organizations, the scheduling process plays an important role. The scarcity of time, resources, money and the abundance of tasks has the process coping with a huge problem. Tradeoffs between objectives are also difficult for decision makers in these kinds of problems. To sum up, "Scheduling is a decision-making process that is used on a regular basis in many manufacturing and services industries. It deals with the allocation of resources to tasks over given time periods and its goal is to optimize one or more objectives" (Pinedo, 2008)

In scheduling problems, resources are named machines and tasks are named jobs. Schedulers are responsible with finding the sequence of jobs which is compatible with machine and time constraints and optimal with respect to multiple objectives. The objectives have various types, like minimizing total completion time or minimizing tardiness.

One way of solving these types of problems is to slightly modify the transportation problem. Operations Researchers call this problem an assignment problem. In this problem, there are a certain numbers of jobs and machines and the decision maker wants to optimize his/her goals by a well matched job-machine assignment. Chapter 2 discusses assignment problems in detail.

1.2 Specific Problem

Flight scheduling in fighter squadrons can be seen as an assignment problem by thinking of machines as pilots and jobs as missions. Unlike most scheduling problems, sequencing the flights is not as important as the mission-pilot assignment. The most important process is matching jobs and machines according to constraints and optimizing the objectives. In Chapter 3, the objectives and constraints of fighter squadron flight scheduling are discussed.

1.3 Scope of the Research

This research focuses on evaluating the assignments of pilots to missions in a specific time period which can be a block of the day or a full day. In this technological era of human life, having pilots schedule flights versus flying themselves is wasting time and resources which are invaluable. If the scheduler could be replaced with a model or have their job automated or made easier, it would be a great time saver and more reliable. This research uses Value Focused Thinking (VFT) with the help of responsible decision makers to develop evaluation criteria to do just that. With this method, a model is made, and this model is used to determine new alternatives (pilot-mission assignments). In Chapter 2, the VFT method is discussed in more detail. Briefly, the process of modeling the scheduler has three steps:

i. Building an evaluation model using VFT (Defining objectives and values).

ii. Using the evaluation model structure to aid the scheduler in manually building schedules (Decision Support System).

iii. Automating the process of pilot-mission assignment with the help of defined values and objectives.

The scope of this research is the first two steps of modeling the scheduler's process and the third step is left as future research.

1.4 Research Objectives

First, this research provides simplicity, flexibility and structured thinking to assignment problems. Specifically, it structures the preferences of decision makers and starts to build assignments to meet the decision makers' objectives. So, it is a value and objective based solution for assignments. Second, it shows the big picture of the current state of the problem to decision makers. The third goal is to change subjective decisions to objective ones. Given an objective model, the decisions will be repeatable and consistent. Finally, the last goal is to reduce the total time it takes a scheduler to do their job. Thus the research question is:

How can an objective assignment matching process be facilitated and accelerated by a flexible computer model?

1.5 Summary

In this chapter, the general and specific problem of this research was discussed. Also, the scope and objective of the research are stated. In Chapter 2, the background of assignment problems, recent research about thesis problems, previous researches in flight scheduling, decision analysis in flight scheduling and the VFT method are discussed. The

methodology is held in Chapter 3 and it is analyzed in Chapter 4. Finally, in Chapter 5, conclusions are presented.

2. LITERATURE REVIEW:

This section states a brief background of the assignment matching problem, followed by previous research. Then, it discusses previous research in the flight scheduling area. Finally, the Value Focused Thinking (VFT) method is discussed.

2.1 Background

"The assignment matching problem is a well known combinatorial optimization problem in the field of Operations Research (OR). There is a plethora of archived research for the assignment matching problem such as the generalized assignment problem, traffic assignment problem, quadratic assignment problem, and the job assignment problem" (Kleeman, 2007). The assignment problem is basically a transportation problem. There is, however, a slight difference between them. "The assignment matching problem is generally described as assigning a number of elements (e.g., people or machines) to a number of positions (e.g., jobs or tasks) with the goal of assigning all elements to positions given a certain cost element" (Kleeman, 2007). The transportation problem is basically aiming to minimize the cost of shipping goods from one location to another so that the demands of every depot or shop are met and every shipping location works within its capacity.

Modeling assignment matching problems using bipartite graphs is generally preferred because they are well known problems for which many polynomial algorithms exist (i.e., many problems are either a form of an assignment matching problem or an extension of an assignment matching problem with additional constraints) (Caseau, 2000).

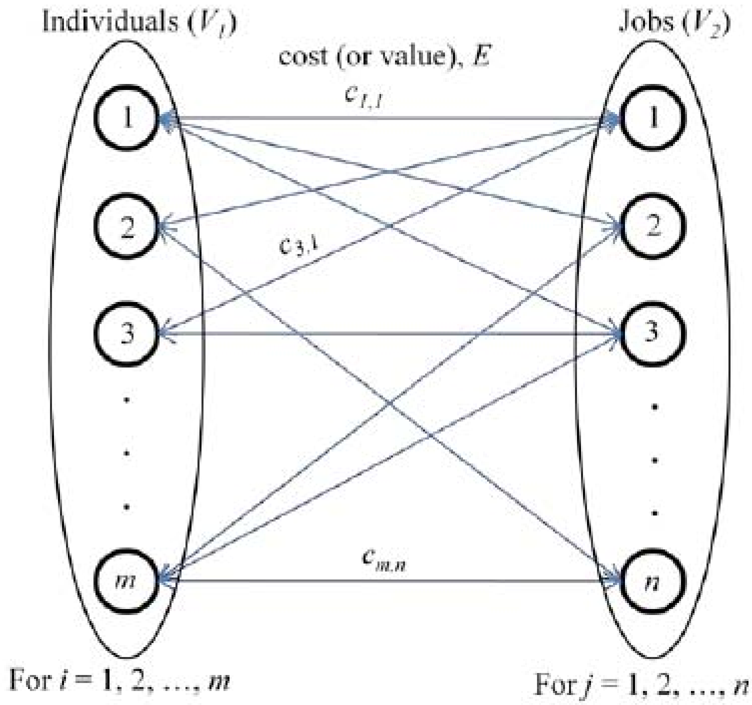


Figure 1: Bipartite Graph Presentation (Caseau, 2000)

In Figure 1, an example of a bipartite graph is shown. The resources are on the left and the jobs are on the right. The arrows define constraints and also the cost of the match.

2.1.1 Recent Research in Assignment Problem

In Jeong's research, he assigns US Air Force new recruits to available jobs. The goal is to find the best assignments in an efficient manner. He modeled this problem as a bipartite assignment matching problem. He uses two multi-criteria optimization techniques, lexicographic optimization and the elastic constraint method, the assignment matching algorithm efficiently produces an optimal solution in a fraction of

the time currently spent (Jeong, 2010). He uses single-objective approach for sub problems but might use multi-objective approach to get better results from them. After all, his model saves significant time for users and meets their goals with high percentages.

2.1.2 Recent Researches in Flight Scheduling

In this section two different methods for solving the flight scheduling problem are reviewed.

Newlon introduces the fighter squadron scheduling problem where the solution method is a mathematical model. As weekly schedules are tedious and can take a long time to complete, using new technology and improvements in mathematical models can be profitable in any squadrons' time consuming problems as well. The main concern in his research is building a feasible schedule if possible. Some of the requirements that restrict the schedules are crew rest, days since a pilot's last sortie, sorties in the last 30 days, and sorties in the last 90 days.

Newlon uses two methodologies to solve the problem and then compares them. The first methodology separates a week into ten blocks and calls them sub-problems. After getting the sub-problems, it starts to solve problems to optimality within the given constraints. The first technique makes updates between blocks of the week. The second methodology considers problems as a weekly schedule and does not separate the week into the parts. It solves the weekly schedule to optimality within the given constraints. This technique has a disadvantage of not being able to update needed pilot

data and other information changed from the first day to the last day of the week. Nevertheless, it takes advantage of optimizing the problem.

Newlon considers the problem as purely a scheduling problem and solves it to optimality with the help of scheduling methods and formulas. The model defines certain number of hours to use for flying, briefing and debriefing, other duties, resting and other work. It limits the time of day allotted for flying and resting. Then the program starts to place the matching of pilot-mission (duty or etc.) to the respective cells in the schedule. Finishing up the necessary placements, the model sometimes needs a generic pilot to fly for the optimization of the block schedule or weekly schedule. That means somebody outside of the squadron will be called to fly for the squadron. Newlon's program penalizes this kind of gap in the model and tries to handle the scheduling problem with the help of the squadron's own resources.

Newlon's research also scopes the construction part of the scheduling problem. As a scheduling problem, the solution model is fast enough to get the attention of responsible people in the squadrons. It solves the problem to optimality in seconds. However, the research mentions that the objective function is rough and that more importance may need to be paid to the objectives instead of the speed of the model (Newlon, 2007).

Yavuz's research is also about automating the weekly flight schedule for fighter squadrons; however, his research is focused on Turkish F-16 squadrons. First, he starts by getting grades for pilot-mission matchings. For calculating these grades, he defines some inputs and formulas in the methodology part. Secondly, he chooses GRASP as a heuristic method because the problem is NP hard and the environment of the

scheduling section is dynamic. Even the grades are not known with complete confidence; schedulers do not use a fixed objective function to get optimal schedules. Also, some other decision makers affect the weekly scheduling problem and having more than one decision maker extends the process too much. He could use a Linear Program (LP) but it would take too much time to get an optimal solution from the program due to lots of constraints and variables. Besides, after getting an optimal solution from this program, there might still be disagreement that it is suitable in real life. Due to these reasons, using a heuristic and consuming minimal time is a perfect choice for that kind of problem.

Yavuz describes two main objectives for the schedulers. The first one is mission currency which means a limitation for a pilot to fly a certain type of mission in a certain number of days to be able to fly solo again in that mission. The second one is the number of flights by every pilot in the corresponding month. Using the automated tool, he aims to make all the pilots current on every mission and schedule them equitably in the corresponding month.

This research has strong points on its speed and updating process. The program is written with MATLAB, provides a weekly program in seconds, and is incredibly faster than a human scheduler. Contrary to past researcher's codes in that subject, Yavuz's code updates matrices related to information concerning pilots and missions after all blocks of a day. However, the research emphasizes only the last step of the schedule process and it does not pay attention to the grading part which decides the objectives of schedule. One problem with the research is schedulers in squadrons are not interested in programs written with MATLAB; they always seem to be interested in visual aided programs that are more understandable and flexible for them (Yavuz, 2010).

2.2 Decision Analysis in Flight Scheduling

In this research, chapter one and previous parts of chapter two talk about the main problems and a more specific problem. The main problems of this research in the Operation Research arena are the scheduling and assignment problems. There are many methods written and created by researchers for approaching these kinds of problems. One of them is reviewed in detail in this section. The specific problem of this research is flight scheduling in fighter squadrons. Many researchers in this area think it is a scheduling problem and apply some scheduling methods to solve the problem to optimality. If we consider the time blocks in squadrons' schedules, we also can think of it as an assignment problem. It is simply a pilot-mission matching problem instead of using some updates while time is passing.

Assignment problems have some weights or scores for a matching and some constraints concerning which matchings can occur. Flight scheduling in fighter squadrons has priorities about pilot-mission matches in a certain block of the day. But it is essential that the priorities are able to change from one block of day to the others. Thus the problem is not a static problem; it is extremely dynamic. Schedulers have major problems deciding the priorities between pilot-mission matches. Some commanders and directors in the squadrons name the objectives themselves while deciding the matches and also have written objectives, limitations and constraints. Finally we can define the specific problem in squadrons as a multi objective decision problem.

In decision analysis, there are two major methods of thinking. The first one is Alternative Focused Thinking (AFT) and it uses alternatives as the basis of the

decision. A project manager gets the alternatives and investigates them for their strengths and weaknesses. After the investigation, he or she presents the results of the research and tries to help DMs think about the problem. The second method is Value Focused Thinking (VFT) and this method starts with building a structure for the values of the DM and organization. It combines everybody's preferences on the subject while constructing the model. After finishing with the model structure, the alternatives can be ranked via this model. The most significant difference between these methods is the starting point. AFT starts by searching for alternatives and VFT begins with searching for values which are important to DMs.

Fighter squadrons are the core unit of Air Forces and they have strict discipline while doing their tasks. So, their decisions about schedules must also have principles and strict guidelines that are not changing because of relocating people in the squadron. Due to the need for a robust decision structure, VFT serves best in this sort of circumstance. Commanders and directors of operation and training sections in the squadron can build a value model structure and evaluate the schedules by the structure to decide on daily or weekly flight schedules.

2.3 Value-Focused Thinking (VFT)

In this research, pilot-mission-time matching is evaluated through the use of Value-Focused Thinking (VFT). VFT is a "structured method for incorporating the information, opinions, and preferences of the various relevant people into the decision making process" (Kirkwood, 1997). VFT is a strategic, quantitative approach to decision making that relies on specified objectives, evaluation considerations, evaluation

measures, and value hierarchies (Kirkwood, 1997). Values are defined as the issues that are important to the decision maker. The VFT process is a sequence of five activities: recognize a decision problem, specify values, create alternatives, evaluate alternatives, and select an alternative (Keeney, 1992). Thinking about values first has some advantages.

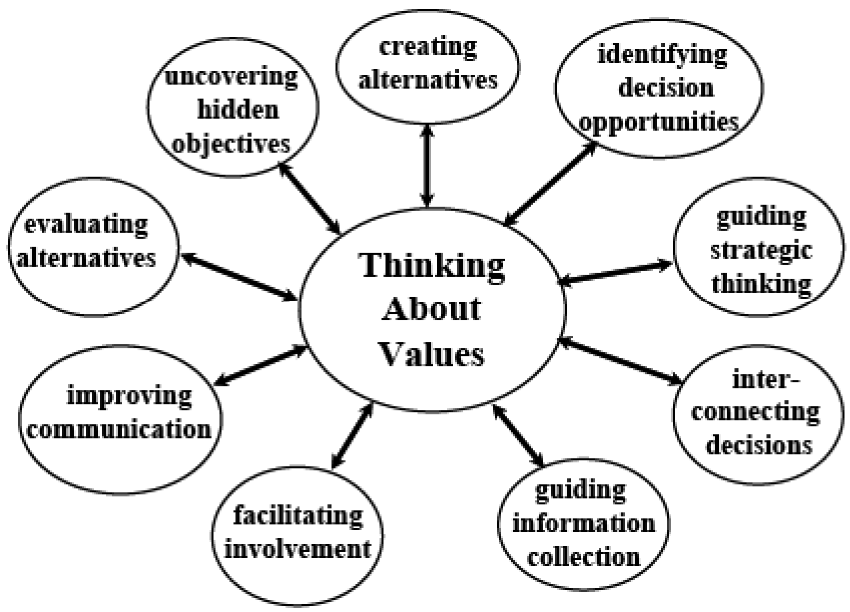


Figure 2: Benefits of Value Focused Thinking (Keeney, 1992)

The figure above mentions some of the advantages that come with the VFT method. By using this method the alternative that has the most value can be seen or it can be created using the stated values.

Shoviak's more detailed VFT method uses ten steps: identifying a problem, creating a value hierarchy, developing evaluation measures, creating single dimensional value functions, weighting the value hierarchy, generating alternatives, scoring the

alternatives, conducting deterministic analysis, conducting sensitivity analysis, and providing conclusions and recommendations. (Shoviak, 2001).

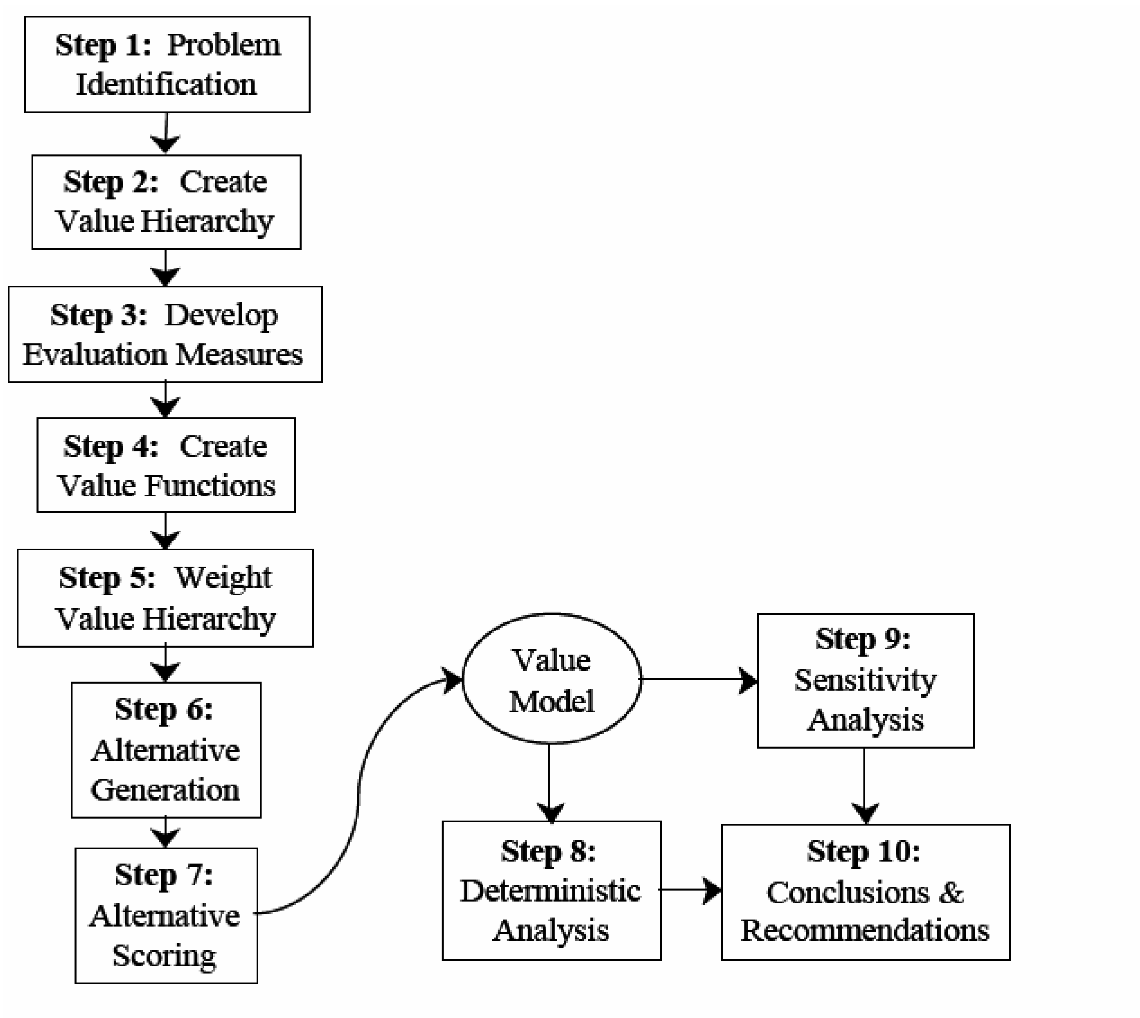


Figure 3 : Value-Focused Thinking 10 Step Process (Shoviak, 2001)

2.3.1 Problem Identification

The process starts with identifying the problem. The major goals in this step are identifying the right problem and identifying it correctly. Although the process begins

with a known problem at hand, it is more important to define fundamental issues correctly and completely. If the right problem is identified and decision makers agree with that, then precious resources will not be wasted.

2.3.2 Create Value Hierarchy

After defining the preferences, objectives and values, this step structures them hierarchically. A "value structure encompasses the entire set of evaluation considerations, objectives, and evaluation measures for a particular decision analysis" (Kirkwood, 1997). The basic questions for this step are "What is important?" and "What do we value?". The first states every possible concern as evaluation consideration; the second defines the desired direction for evaluation considerations as objectives and finally assesses them by a scale and is called an evaluation measure. Kirkwood says that when a value structure is organized hierarchically, the structure is called a value hierarchy (Kirkwood, 1997).

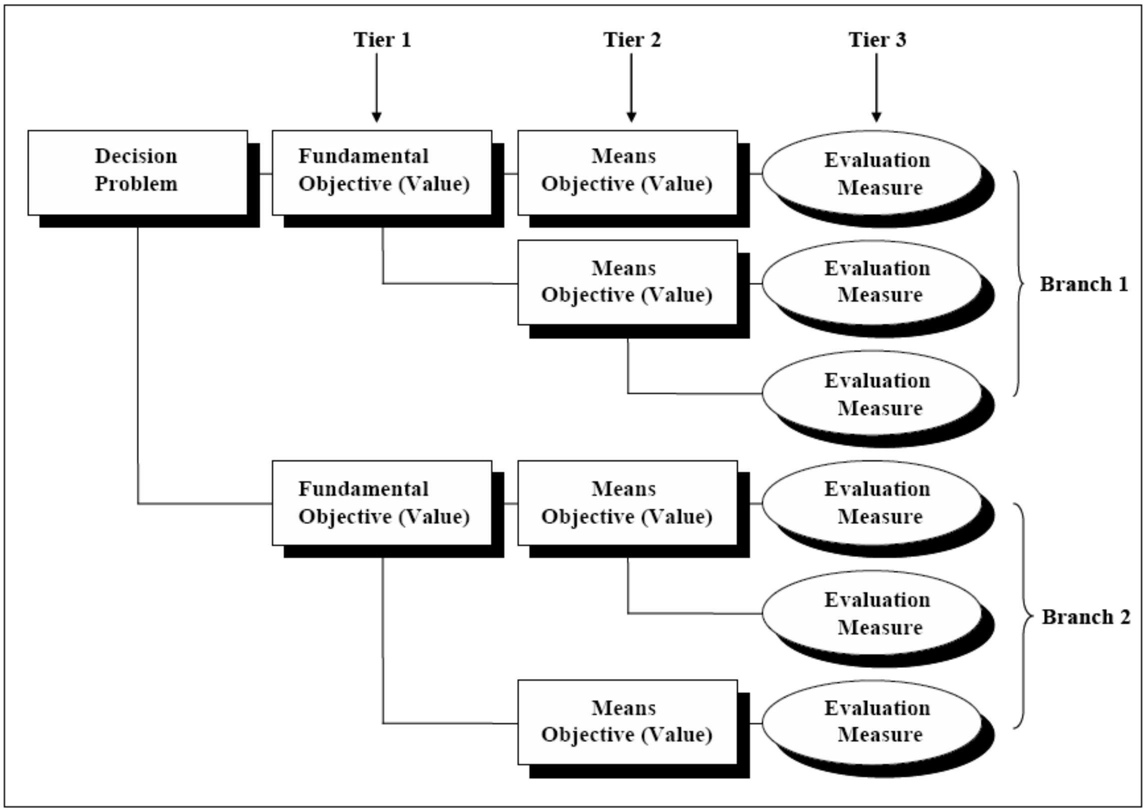


Figure 4: Example of a Generic Value Hierarchy (Jeoun, 2005).

The figure above shows the generic version of a value hierarchy. In this structure the first box is the main question or the main problem. After revealing the top box, the rest of the structure consists of tiers and branches. A tier consists of all the evaluation considerations that are the same distance from the top of the hierarchy (Kirkwood, 1997). Branches are composed of all the objectives and evaluation measures that derive from a single evaluation consideration (Bulson, 2006).

A value hierarchy has five desirable properties: completeness, non redundancy, independence, operability, and small size (Kirkwood, 1997). Completeness means covering all evaluation concerns for the problem. In a non-redundant structure, evaluation considerations should not overlap. Completeness and non-redundancy is often called

collectively exhaustive and mutually exclusive. Independence in a VFT structure is defined as preferential independence. If a decision maker's preference for the level of one evaluation measure does not depend on the level of the other evaluation measure, the value hierarchy is preferentially independent. Operability and small size properties facilitate each other. They are for increasing understanding and usability by decision makers or subject matter experts.

2.3.3 Develop Evaluation Measures

The next step in the process of building a VFT structure comes with the question "How can we evaluate what we value?". Defining objectives and values in the first tiers, the last tier of the hierarchy takes place with the measures that evaluate the objectives and values above them. For instance, if we choose income as a value in our structure, we could select annual income of the company/family in dollars as an evaluation measure of this value at the last tier under the branch of income. After defining the name and the unit of the measure, we have to state the range of it. Again in our example, we could determine the range of annual income in dollars as zero to one million. This range is important to specify because later steps will apply it to some formulas and some graphs for obtaining the final scores of the specific objective evaluation.

2.3.4 Create Value Functions

In order to evaluate values, we attain measures in the previous step but we need to acquire some formulas or graphs to convert measures to numbers. Furthermore, because the structure possesses several values to evaluate and compare them to each other, we also desire to get normalized scores from all individual values. VFT answers

these questions by Single Dimensional Value Functions (SDVF). All values are evaluated via their SDVF's and finalized with zero to one ranged scores.

Considering the values of the problem we do not always have quantitative measured values. At this point, the SDVF method helps. By this method, the DM or SME can be questioned and a function with zero to one ranged scores can be achieved. For example, we could choose motivation of the students in a primary school as a value in our hierarchy and the measure could be happiness level. It seems to be a tough value to evaluate by formulas or quantitative methods. But building a SDVF by questioning teachers and students and their observation of happiness, we could have a score that ranges zero to one and use it in our model.

2.3.5 Weight Value Hierarchy

Most of the decision problems are multi objective decision problems and there are priorities between these objectives. In the VFT structure, if the objectives were equally important, we would add the scores of all branches and finish up with a final score. However, real life makes the situations more complex and humans compare and prioritize objectives in their minds. Thus we cannot simply assume equal importance. These prioritizations generate the next step in VFT. This is called the weighting process. There are two general ways of weighting a value hierarchy. The first one starts from the bottom and is called global weighting. At the bottom of the structure, the DM is asked to consider the differences of values and weight them for the purpose of arranging a preference order. In spite of the advantage of seeing all the values and having a preference order, this method can be tedious when we are weighting a large structure. At this point, the second method of weighting is useful and is easier to apply. It is called

local weighting and it starts from the top of the structure. In this method, the DM is asked to order preferences by branches. The most challenging disadvantage in this method is inconsistencies between branches can occur in some models. This can be corrected by calculating and inspecting the global weightings after finishing with the local weighting process. Another difference between methods is global weighting where the sums of the bottom tiers' weights sum to one but on the other hand local method sums each branches' weights to one.

2.3.6 Alternative Generation

The previous steps introduce the framework to the DM for thinking about the problem comprehensively. In this step, alternative solutions to the problem must be generated. Alternatives can be present or waiting for discovery. Sometimes there will be large number of alternatives to be scored; because of this, the DM might want to eliminate some of the related alternatives. Usually, a screening method works well in order to solve problems with high number of alternatives but it is essential to pay attention while deciding screening criteria. Due to inaccurate criteria, the model can miss good alternatives and the great effort made for structuring the model might be wasted.

The second type of problem is having too few alternatives to solve the problem. Then, VFT presents help so that the DM can use the values that he or she defined before and can develop other alternatives. Certain values can be discussed to maximize their scores and this method aids the DM in developing smart choices as alternatives.

2.3.7 Alternative Scoring

This step brings a data search task for the modeler. Former steps state the measures and alternatives, and then the model needs information about the measures of alternatives. So the modeler has to ask DMs or SMEs for needed data or try to get data from related databases.

2.3.8 Deterministic Analysis

In order to determine an overall score for each alternative, an additive value function is used. The form of this function is a weighted sum of the single dimensional value functions over each evaluation measure (equation shown below) (Kirkwood, 1997).

$$v(x) = \sum_{i=1}^{n} w_i \; v_i\left(x_i\right) \tag{1}$$

Where:

$v(x)$ = overall score for alternative x

w_i = global weight for evaluation measure i

$v_i(x_i)$ = value score for alternative x from SDVF for measure i

x_i = score for alternative x on measure i

n = total number of evaluation measures

Alternatives can be shown in an order based on the final scores. The order is constructed with the weights and SDVFs the modeler made by soliciting the DM or SMEs. Thus we cannot say the order is certain due to the fact that we created the model with the help of a non-calibrated DM.

2.3.9 Sensitivity Analysis

As mentioned in the previous step, a deterministic analysis is not an absolute and reliable analysis for a decision. Weights and value functions are manmade and humans can make mistakes while building the model. It is mostly seen that humans have overconfidence when they are solicited for probabilities or information they usually work on. Another widely seen error is making biased decisions so that we cannot be sure about the numbers we acquired from DMs or SMEs.

A sensitivity analysis can be run by the modeler to show how changes in weights affect changes in final scores. Decision makers usually have certain ranges in mind but they do not have certain numbers. It is dangerous to say this branch's weight is a certain number; however, we can ask for a range of weights. By conducting a sensitivity analysis on this range of weights, the modeler can bring some other results to light and make DMs think again about their choices of weights and the final decision.

2.3.10 Conclusions and Recommendations

This step contains conclusions and recommendations. The modeler can list some solutions for the problem by the aid of deterministic and sensitivity analysis. An important nuance the modeler must pay attention to is that using these decision models is not making decisions for DMs; it is only giving them a picture of the situation from an aspect they cannot see without the model.

3. METHODOLOGY

In this research, a new approach is used for the Air Force Fighter Squadrons' pilot scheduling problem. This chapter states the definitions and specifications of flight scheduling in fighter squadrons and then implements VFT for modeling the solution to this problem.

3.1 Flight Scheduling in Fighter Squadrons

In this section, the general information about flight scheduling in fighter squadrons will be revealed. Also, the variables, objectives and resources of the problem will be explained.

3.1.1 Flight Schedules in Turkish F-16 Squadrons

In F-16 Squadrons of the Turkish Air Force, there are approximately five people who are responsible for structuring the schedule. One of them is a director, two or three of them are planners and the others are assistants. The planner of the week starts to make the weekly/daily schedule with the help of assistants and computers. After having an initial schedule, the director reviews it and makes changes or comments. In the light of this information the planner revises the initial schedule. This procedure continues until the director approves it. However, the process doesn't finish here. A similar period is seen after this approval when the Squadron Commander (SC) comes into play. The schedule is only final after the SC is satisfied with it and signs it to be published.

Considering this process, the general problem is that there are lots of hands and eyes on the schedule. They all have rights to change it and add their opinions according

to their objectives. These circumstances make this operation unstable, subjective, and challenging. After reviewing the process and naming it as the general problem, we have the specific problem which is the schedule itself. The planner has a variety of inputs and a lot of alternatives for output. Also, there are constraints that may change during the course of time. The planner is an active pilot as well. He/she makes mission planning, participates in mission briefings, flies and takes part in debriefings.

To sum up we have one human brain which is full of other thoughts, on the other hand there are lots of variables, constraints and decision maker inputs to consider for the scheduling problem. Beyond all that is a time constraint to finish this job.

3.1.2 Flight Schedule Variables

Normally, schedules have two or three time blocks. These are morning (AM), afternoon (PM) and night blocks. In each block we can simply see mission types, plane numbers, pilot names, area names and times of events (take off, landing etc.). Under all information of blocks we also have duty types and pilots on duty. This is the big picture for a daily flight schedule.

3.1.3 Missions

Basically there are two types of missions. First are operational missions. Those are not scheduled by squadrons. They are assigned from headquarters and then squadrons only schedule pilots to plan and fly them. Second are training missions. Those are scheduled by squadron planners. There is a variety of training mission types. The planner is mainly concerned with the pilots who can fly the mission and after that thinks about the

needs of the plane type and count. At this point we meet a term which is currency. If we say this pilot can fly this mission with a one-seat plane this means the pilot is current on this mission. It is a strict constraint for the planner to pay attention to currencies during flight scheduling. On the other hand, currency shows pilot's readiness for missions and generally for fight. Considering squadrons' goals, we may name currency as the main objective for the schedules.

3.1.4 Planes

In F-16 squadrons there are two types of aircraft. According to seat count, they are named the F-16C (single-seat) or F-16D (double-seat). As we learned before a pilot which is current for a mission can fly with a single-seat plane on this mission. But if the pilot is not current on a mission or he/she needs some orientation, he/she can fly in front cockpit of F-16D with an instructor seated in the rear cockpit. Everybody can fly any mission in rear cockpit of F-16D with an instructor or four-ship leader seated in the front cockpit without concerning currency limitations.

3.1.5 Pilots

There are two ways to divide pilots into groups. The first one is by position in the squadron. The Squadron Commander is the number one, Operations Officer is second and Director of Flights is third. After them we have positions about flights. The second way to divide them is by flight experience. The pilots who are most experienced and have passed the instructors course are called instructors. They can fly in the rear cockpit to teach new pilots. After them, four-ship leaders come next in the queue of experience. They can fly with a four ship formation in the flights and they are responsible for the

mission all the time starting from planning until debriefing finishes. Two-ship leaders can be responsible for two ship formation flights. Other than leaders there are wingmen who are flying the missions but they are not responsible for the others like leaders. Instructors and four-ship leaders can fly in every position in every formation. Two-ship leaders can fly in third place of four-ship missions, first place of two-ship missions and also as wingmen for any mission. Wingmen are allowed to fly in second or fourth positions of two and four-ship missions.

3.1.6 Objectives

Every pilot has to fly a certain number of flights in a year. Planners divide this number into months and want to obey this rule to have all pilots equal in number of flights. This is the first objective of planners. This certain number of flights called a scheme. In addition to concern about general pilot scheme status, the director has to pay attention to the type of pilots and their status of scheme in their related groups. The second objective is currency which is also a constraint in a flight schedule. Currency is the most important objective in squadrons because the Air Force wants pilots to be ready for combat. They can only get this readiness information from currencies.

3.1.7 Constraints

After introducing elements of the schedule we have to consider limitations while matching mission-pilot-plane-time. First, pilots can only fly in two blocks of a day. One can be in the morning and the other one afternoon or one can be afternoon and the other one at night. If somebody flies in the morning he/she can’t fly at night in the same day.

The reverse is also true for this constraint so that if somebody flies at night then he/she can't fly in the next morning block.

The next constraint is about currencies. Every pilot type has their mission currency program. For example, four-ship leaders and instructors can be current 60 days from mission 1 but the others can be 45 days. Considering these changing constraints, planners choose the mission type and pilots to schedule. If a pilot is not current for a specific mission he/she can't fly this mission in an F-16 C. He/she can fly with an F-16 D and an instructor pilot must be in the rear cockpit. After this type of flight he/she becomes current if the sortie is successful.

Pilots have currency status from individual missions and they have general currencies for day/night sorties as well. It is the same as individual mission currencies but it affects all mission capabilities for pilots. For instance, if a pilot doesn't fly a day/night sortie and doesn't land the plane by him/herself in that sortie, he/she can't fly any other day/night sortie with an F-16C so that this pilot has to be current for landing before getting permission to have day/night F-16C missions.

There are limitations for maximum flight time and sortie counts for pilots to be scheduled in a day/month/year. For example the rule may say a pilot can fly no more than 4 hours and 3 sorties in day. The planner must obey this kind of maximum limitations and also crew rest for pilots. Crew rest is a rule about minimum rest time for pilots. According to the flight schedule nobody can be in the squadron when he/she is supposed to be resting.

Duties during flights are major constraints because the pilot on duty can't be scheduled for a flight mission.. There are three duties to be planned for flight time. Two

of them have to be held by four-ship leaders or higher experienced pilots. The other one is allowed to be held by all pilots that have general currency.

3.2 VFT Implementation

In this section, the method of VFT is implemented to solve the first and second step of modeling the scheduler problem. By using a VFT model, manually built alternative schedules can be evaluated and other good alternatives can be created by means of the structured values.

3.2.1 Step 1: Problem Identification

In this step of the VFT method, the major concern is identifying the right problem and identifying it correctly. If we cannot name it correctly, it will be a waste of time to solve the wrong problem. Previous sections mention some obstacles that trouble schedulers. For example, having more than one DM makes the problem seem bigger than it is and undefined objectives add complexity to the schedulers' decision environment. Because of these difficulties, people responsible for the schedule have to think about building a structure for all their objectives and values to get rid of this complex environment. Nevertheless, they need a starting point to begin their work for the structure. They ought to decide the top box question first. Before deciding this vital question, the known and unknown inputs must be analyzed.

Previous parts stated some variables, constraints and limitations for the problem. For instance pilots, aircraft, missions and time periods are the variables. Before the scheduler starts his or her work, pilot presences, currency data, aircraft availabilities, approved mission types and approved time periods are known. However, the major

unknown part for the planner is how to match the resources in order to satisfy all the objectives and obey the limitations and constraints at the same time. The process can be thought of as two phases. First, the matches are made and then the matches are fitted to the constraints and limitations. The first phase is a decision analysis part and the second is a math programming problem. If the matches are made by a decision analysis model which is structured by the help of decision makers, the major obstacles would exceed the hardships of the problem and yet a math model can solve the other fraction of the problem without meeting barriers of DMs.

After revealing the known and unknown inputs to scheduler's work, the top box question can be decided. It could be "What is the value of pilot-mission match in a specific block of time?". Aircraft also might be added to this match but as a resource, we do not have much differences and objectives to match aircraft to pilots or missions. Aircraft counts can be used as a constraint or a limitation in the same specific time period. Finally, the problem identified for this research is deciding the value or score of the pilot-mission match at the defined time period.

3.2.2 Step 2: Create Value Hierarchy

The next step is asking the DMs for their objectives and values and then combining them with the written objectives and values of the Air Force. After all, the structure of the decision model will be built hierarchically by means of these combinations. While gathering values together, it will be crucial to pay attention to the necessary properties of a value hierarchy. As a reminder, Chapter 2 mentions the

desirable properties as completeness, non-redundancy, independence, operability, and small size. For example, when caring about completeness, operability should be considered as well.

In fact, Step 1 is the starting point of Step 2. After writing the identified problem in the top box of the hierarchy, the solicitation part begins. DMs and SMEs are asked for the values and a list of values is considered to be the first tier of the value hierarchy. Due to the non-redundancy property some of the values were eliminated. Finally, four major values are used for composing the first tier.

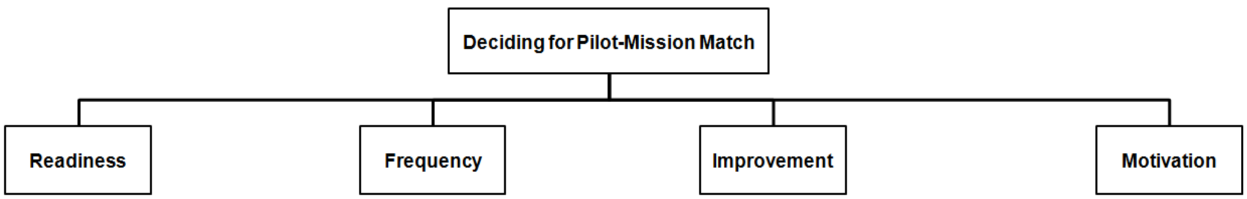


Figure 5: Top Box and First Tier of Value Hierarchy

As shown in Figure 5, Tier 1 consists of Readiness, Frequency, Improvement and Motivation values. These major values are not written exactly like this on the formal papers but while comparing Air Force objectives and values concerning schedules, similar goals take over.

The Air Force is a weapon for countries while they are defending themselves from their enemies. Because countries can encounter conflicts or crisis all of a sudden, this vital weapon must be ready for the fight all the time. Squadrons are the warrior unit of the Air Force and fresh warriors mean a lot for the game plans. So “Readiness” is an organizational goal and a necessity for the squadrons. If fighter squadron functions are examined individually, they separate into two main groups. The first one is air to air and the other one is air to ground. In spite of the fact that they are tasked differently, they still

need to be ready for other missions than their specialty. Hence the total mission count for pilots to fly regularly becomes extremely large.

The Readiness value in this hierarchy introduces the score of the pilot-mission match by the means of readiness in accordance with a time period. The score from this branch tells how much a specific pilot needs a specific mission for his or her freshness in a stated time block. Every squadron has approximately 30 pilots and 50 mission types, so the match count will be roughly 1500. After evaluating the readiness value, the scheduler will know the effect of the 1500 pilot-mission matches on the squadrons' readiness.

Pilots must fly not only for readiness but also for becoming a frequent flyer. There are a certain number of flights for pilots to fly in specific time periods. Schedulers pay attention to choose the right missions for the pilots, but they also want them to fill their scheme stated by the Air Force. There must be a balance between pilots because of the mandatory flight counts that are revealed at the beginning of every flight year. Besides this necessary balance, planners also have to balance between the readiness of pilots and the frequency of flying. For example, a scheduler sometimes has to match a specific pilot to a mission which he or she flew one block ago to increase this pilot's flight count in this month to catch up with the other pilots' flight numbers. We can draw another picture worse than that. In the same example, another pilot may need this mission on this specific block because of currency problems; nevertheless, the scheduler sometimes chooses frequency prior to readiness and this pilot becomes non-current due to priorities. To sum up, the decision model of the pilot-mission match separates readiness and frequency values as two branches and needs a priority plan to select one of them if the scheduler has to.

Another property of the value structure is completeness, so all concerns of the scheduler and commanders must be evaluated in this structure. At the beginning of Chapter 3, some differences between pilots were revealed. They are separated into groups by their experiences such as instructors, 4-ship leaders, 2-ship leaders and wingmen. A graduated pilot becomes a wingman first and after that position, he/she follows some program to be a leader. With these programs, pilots start to improve and get experience in the squadron. Another type of improvement is getting used to bad weather and night conditions through categorical programs. Furthermore, pilots who have not flown for a long time or newcomers are also subject to some refreshment and training programs to improve from their low level position to another pilots' higher level position. It is important to keep every individual pilot on track with respect to any program he/she may be in. So the decision about the pilot-mission match is affected by this improvement concern.

An important task of commanders is being aware of the psychological status of the elements in the squadron. Commanders have to keep track of pilots' level of motivation and react early when something is wrong with them or their family. A branch of pilots' interests about the schedule is also in the value structure to track their needs and hence motivation of the squadron could be boosted by this action. Due to qualitative conditions and unknowns, this is the hardest part for the model to build, but it is known that a value structure does not evaluate all values equally. It uses weights solicited from DMs to calculate an overall score; so defining a motivation branch can have as much affect on this score as the DM's want and is a good start for evaluating the motivation affect on the pilot-mission match decision.

3.2.3 Step 3: Develop Evaluation Measures

This step accommodates two phases. Namely, choosing the right evaluation measures for the associated value and deciding the range of the evaluation measure in order to use this range in further steps. After defining values, the work for collecting measures to evaluate them starts. The following sections explain the measures for the four major values.

3.2.3.1 Measures for Readiness

All commanders agree that the most important value is being ready for the game plan. But there are not enough written rules to measure schedules in terms of this value. The only written rule is currency limitations for missions. Currency is discussed in previous parts of this section, and it basically means a limitation of days that a pilot can fly a specific mission. A fighter squadron has roughly 50 missions. Table-1 shows an example of a fighter squadron spreadsheet of official flight types and mission numbers. AA, AG and NI mean air to air, air to ground and night, respectively. The type column groups the same types of missions together; thus, there are two numbers for all missions. The first one is the mission number and the other one is the order number of the specific mission in its type.

MISSIONS	TYPES	MISSIONS	TYPES
M-1	AA-1	M-26	AA-9
M-2		M-27	AA-10
M-3		M-28	AA-11
M-4		M-29	AG-1
M-5		M-30	
M-6		M-31	
M-7		M-32	AG-2
M-8		M-33	
M-9		M-34	
M-10	AA-2	M-35	
M-11		M-36	
M-12		M-37	
M-13		M-38	AG-3
M-14		M-39	
M-15	AA-3	M-40	AG-4
M-16		M-41	AG-5
M-17		M-42	AG-6
M-18		M-43	
M-19	AA-4	M-44	AG-7
M-20		M-45	NI
M-21		M-46	
M-22	AA-5	M-47	
M-23	AA-6	M-48	
M-24	AA-7	M-49	
M-25	AA-8	M-50	

Table 1: An Example of Mission Numbers and Types Table

As far as currency concerns, official papers do not define the number of current days for every individual mission. First, there are written currency limits for day and night missions generally. So nobody can fly a day/night mission if he/she is not current in terms of the currency limits and this is called a general currency limit for the flights. There are some critical missions that have special currency limits. For instance, an air refueling mission has a special currency limit and schedulers keep track of the last flight date of this mission for every pilot. Furthermore, types of missions can have a currency

defined for them as well. From Table-1, AA-1 has nine missions and standard operation procedures can define a currency limit for AA-1 itself. Thus, when somebody flies one of the AA-1 missions, he/she can be current for all of AA-1 missions. Finally, the Air Force can state currencies according to the experience level of pilots. While an instructor can be current for 60 days for a night mission, a wingman has to fly the same mission every 30 days. Because of the complexity in currency calculations, a spreadsheet for every pilot is prepared to track the last flight date of every mission.

The Air Force gives much weight to currency limits, and the scheduler has to watch these numbers carefully. Because of this, the readiness value contains currency as an important evaluation measure. But currency does not provide all of the readiness anxiety. Currency limits are somewhat large limits and if other numbers are not defined beside the currency limits, the scheduler has to choose which mission to fly more than the others. The scheduler not only keeps mission currencies fresh but also tries not to keep aircraft on the ground. This problem can be solved by defining some other readiness limits for specific missions that are more important than the others according to the fighter squadron' game plan and commanders' view. The following figure shows the readiness value and its measures. DMs are asked for the wanted readiness limits pilot by pilot and mission by mission. Then a spreadsheet that tracks pilots' wanted readiness level is constructed.

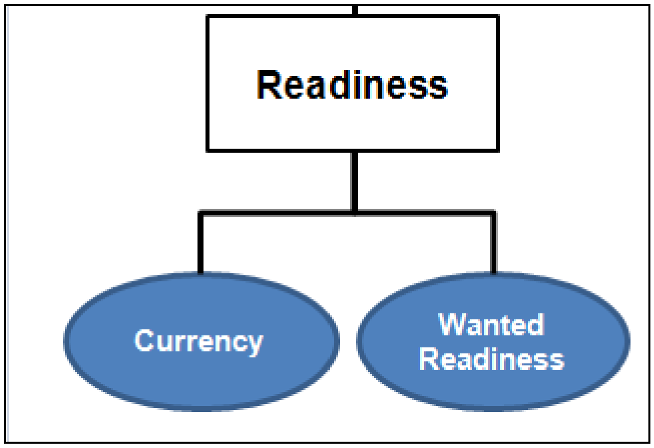


Figure 6: Evaluation Measures for Readiness

3.2.3.2 Measures for Frequency

Frequency of flight for pilots means how many flights a specific pilot flew in a specific time period. From this starting point, we can say that the Air Force declares yearly and monthly schemes for pilots every year. In the readiness part there is the written and strict measure of currency, but besides this measure, the DM uses another measure which is not written and strict but is needed for scheduling. Frequency is considered similar to readiness and so will have official measures that are yearly and monthly schemes declared by the Air Force but schedulers need another measure for weekly and daily concerns.

Yearly and monthly schemes can change every year but they are simply numbers, approximately 120 and 8, respectively. This means a pilot in the squadron has to fly 120 flights in this year, but there is no constraint about mission types. So a pilot can fly one certain mission type 120 times, and it will not be a problem from the aspect of the Air Force yearly scheme considerations.

Commanders have some optimum numbers of weekly flights and daily flights for every experience level in their minds. For example, they can say a wingman has to fly everyday or define one flight as the optimum number of flights for everybody. Thus zero flights or two flights will be penalized due to the optimum number. This can also be done for weekly flights. DMs are asked for the optimum numbers of daily and weekly flights; then they are applied to the model as weekly wanted and daily wanted measures of frequency.

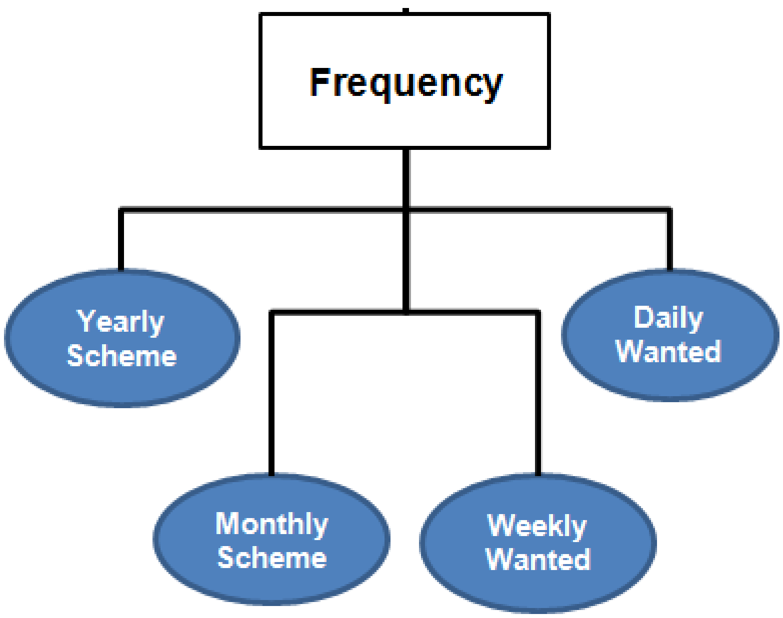


Figure 7: Evaluation Measures for Frequency

Figure 7 shows the evaluation measures for the frequency value. The first two measures are taken from formal papers and the other two are asked from DMs.

3.2.3.3 Measures for Improvement

The Improvement value is concerned with the effect a specific pilot-mission match has on specific pilot's improvement in his/her flight experience. DMs are asked for how to evaluate improvement of pilots, and according to their perspective, the following figure shows evaluation measures for the improvement value in the pilot-mission match value hierarchy.

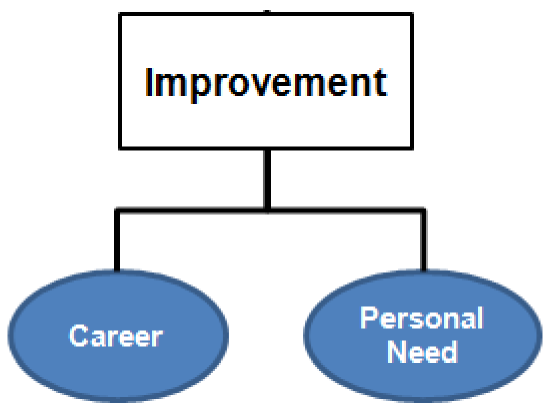


Figure 8: Evaluation Measures for Improvement

The Career part measures to what extent a certain match helps pilots' experience, refreshment or categorical programs. For example, if a pilot needs M-1 for his/her refreshment program, this pilot's match to M-1 will be more valuable in terms of improvement. According to the SME's views, spreadsheets are prepared for tracking pilots' levels in these programs and every possible mission is graded by this data.

MISSIONS	CAT-III	CAT-II	CAT-I	BEGINNER	2 SHIP LEADER	4 SHIP LEADER	INSTRUCTOR	REFRESHMENT	TOTAL
M-1	0	0	0	0	0	0	0	0	0
M-13	1	0	0	1	0	0	0	0	2
M-23	0	0	0	1	0	0	0	0	1
M-42	0	1	0	0	1	0	0	0	2
M-50	0	0	0	0	0	0	1	0	1

Table 2: An Example of Career Spreadsheet for Pilot X

Table 2 is an example of the career measure spreadsheet for generic pilots. From this table, M-1 has no affect on the first pilot's career. But the second line shows a newcomer and M-13 for this newcomer means a lot in his improvement. The third line introduces another newcomer's position in the track; however, M-23 only affects the beginning program. The fifth line reveals a need for M-50 for a pilot who is preparing to be an instructor. An important property of these programs is nobody can be on more than two career programs. So the career range is from zero to two.

The second measure for the improvement value is personal need. Every pilot has debriefing notebooks. After all flights, leaders or instructors write strength and weakness points based on the previous flight. Using this notebook, the training section can track pilots' conditions for specific mission types. However, nothing happens automatically after a pilot does bad or good in his/her previous flight. A range can be defined for evaluating the flights by leaders or instructors and then if a pilot satisfies his/her leaders' goals in a specific mission, he/she will get a good grade. By means of this evaluation, personal needs can be revealed and future schedules built being aware of the previous flights' success or failure. A spreadsheet is prepared for keeping the grades of all

missions by the training section, so this model can use this data to evaluate the personal need part of the improvement value.

MISSIONS	LAST FLIGHT DATE	PERSONAL
M-1	12/13/2010	5
M-2	12/14/2010	3
M-3	12/15/2010	1
M-4	12/16/2010	2
M-5	12/17/2010	4

Table 3: An Example Personal Need Evaluation Table

As seen in Table 3, a spreadsheet for the personal need part has mission numbers, last flight date for respective mission and evaluation of the mission by an experienced pilot. For example, this pilot has no need for M-1 and M-5, but he/she needs to fly M-3 again as soon as possible. The range for personal need measure is defined as [1-5].

3.2.3.4 Measures for Motivation

The following figure introduces evaluation measures for motivation value in the model.

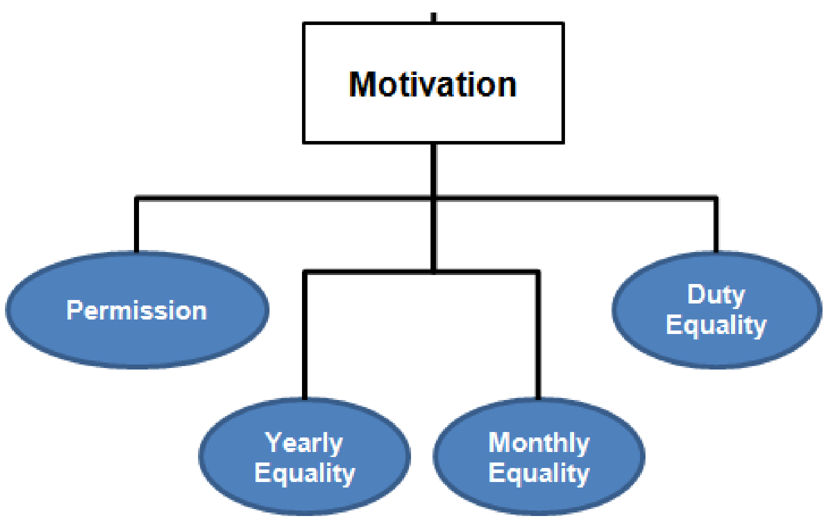


Figure 9: Evaluation Measures for Motivation

Motivation is the hardest value to evaluate for pilot-mission matches. Every commander or leader accepts that the task for keeping pilots motivated is their responsibility, but they do not have any structured way for thinking of it. In order to make a good start for evaluating the effect of matches on motivation, DMs and pilots are solicited for the purpose of creating the motivation part of the hierarchy. Some of the concerns that come from pilots are the same. Thus the motivation part is constructed as shown in Figure 9.

Pilots have challenging and difficult work every day. Flight and office hours are changing a lot because of the dynamic environment. Hence, they do not have an orderly family or private life. Eventually, they have hardships when they need time to take care of issues related to their private life. At that point, permission decisions come into question and have an effect on the pilot-mission-time match evaluation. Sometimes pilots want permission not to fly on a specific day in order to handle their other activities. Nevertheless, there currently is no decision model for responding to their desires. Commanders deal with these kind of requests throughout the flight year and they use their conscience and logic together to be fair. DMs are asked for their thoughts about how they answer these questions. A spreadsheet and a formula are made by using their logic for evaluating the permission part of the motivation value.

WANT TO FLY?	PAST REQUESTS	PAST RESULTS	PAST PERCENTAGE
0	1	1	1
PERMISSION			
1			

Table 4: An Example of a Spreadsheet for Evaluating Permission Requests

The above table presents an example for an evaluation of a permission request made by a generic pilot at a certain block of time. The first cell asks the pilot whether he/she wants to fly at that time period and answers are numbered as negative (0) and positive (1). Starting from the second cell, data from the past is evaluated and then the permission evaluation result is given in the last cell. In this specific example, the pilot does not want to fly in this block and the permission calculation comes up with a positive result due to his/her past requests and the negative/positive replies to them. Finally, permission points will affect the overall grade of motivation value gradually. Using a structured way for permission decisions and welcoming pilots to participate in decisions will help increase the squadrons' motivation.

Pilots from every level of experience desire to fly an equal number of flights in a month or year. Because of this, they watch the flight counts of the other pilots at the same level of experience. If there is a significant difference between them, they become upset. In order to evaluate this stress on pilot-mission matches, a spreadsheet is prepared and schedulers pay attention not to make mistakes about equality. When pilots are solicited about the feelings from these situations, they mention two types of equality that are important to them. The first one is yearly and the other one is monthly equality. They are asked about the value of the differences and the range for monthly or yearly equality and evaluation measures are built. They state that a difference of two flights in a month or five in a year is not important but above these numbers they start to get concerned.

YEARLY FLIGHT	MONTHLY FLIGHT	YEARLY MAX	MONTHLY MAX	YEARLY DIFF	MONTHLY DIFF
19	3	35	5	16	2

Table 5: An Example Spreadsheet for Evaluating Yearly/Monthly Equality

Table 5 shows an example of evaluating yearly and monthly equalities. The first two cells are the flight counts of a generic pilot in this year/month. The third and fourth cells contain the number of flights of the pilot who flew more than all others at his/her level of experience. The last two cells calculate the differences the model will consider. Hence, the matches will be graded according to these equality concerns. For example, this pilot's equality part will be graded separately due to the importance of yearly and monthly differences. The yearly difference is sixteen and it is valuable to schedule this pilot to a mission in this block, but the monthly difference is two meaning there is no significant difference in this month between pilots at this level of experience. Finally, this pilot will get a medium grade from a flight in that block due to the aim of decreasing yearly differences. For this measure, maximum numbers were chosen for the evaluation input differences rather than averages as they do not tell the same story.

YEARLY FLIGHT	MONTHLY FLIGHT	YEARLY MAX	MONTHLY MAX	YEARLY DIFF	MONTHLY DIFF
19	3	35	5	16	2
		YEARLY AVG	MONTHLY AVG		
		19	3		

Table 6: An Example for Evaluating by Average Numbers

For instance, yearly and monthly average numbers are added on the same example as shown in Table 6. It can be easily seen that the same pilot would not have a good score from a mission match because his/her flight number is equal to the average in the squadron. Nevertheless, the maximum flight number is sixteen more and the model does not evaluate this nuance if the average is used as the difference indicator.

The final evaluation measure for motivation is duty equality. In fighter squadrons, there are several duties during flight hours and related to flights but only two of them are being considered as important with respect to the pilots' views. The Director of duties

tries to pass out these duties equally and fairly. The DM is asked for his opinion on deciding fairly and according to his views a spreadsheet is prepared for keeping track of past duty data for the purpose of evaluating equality on duties.

DUTY 1	DUTY 2	TOTAL	TOTAL MAX	DIFFERENCE
4	0	4	8	4

Table 7: An Example Spreadsheet for Evaluating Duty Equalities

Because the duties are during flight hours, a pilot who is on duty cannot fly. If the count of duties is not equally distributed, some of the pilots will be affected by the means of currency and frequency. So, duty equality means a lot for the motivation value. In Table 7, an example spreadsheet for evaluating duty equalities is presented. This sample pilot has had duty 1 four times in this flight year. The first two cells indicate the counts for duty 1 and 2. The third cell gives the total number of duties held by the sample pilot and the fourth cell reveals the maximum total count of duties held by a pilot at the same level of experience. The fifth cell states the difference between the sample pilot and the pilot with the maximum number of duties. Using the difference, the model will come up with an inverse ratio scoring for the duty equality part of the motivation value. For example, in Table 7 there is a four in the difference cell and the sample pilot will have a low score from the duty equalities part which means he/she can get another duty because he/she has less duty counts than someone at his/her level in the squadron.

The following table introduces all evaluation measures and their units. As an example, currency is an evaluation measure with a range [0,120] and this number shows the remaining current days for a pilot. The developing evaluation measures step contains ranges and units for measures and is used in further steps.

	Range	Unit
Currency	0-120	Remaining Current Days
Wanted Readiness	0-120	Remaining Ready Days
Yearly Scheme	0-1	Yearly Ratio (Need/Presence)
Monthly Scheme	0-1	Monthly Ratio (Need/Presence)
Weekly Wanted	0-1	Weekly Ratio (Need/Presence)
Daily Wanted	0-1	Daily Ratio (Need/Presence)
Career	0-2	Matched Flight Count
Personal Need	1-5	Success Point in Last Flight
Permission	0-1	Past Result Percentage
Yearly Equality	0-30	Yearly Flight Differences at Same Level
Monthly Equality	0-8	Monthly Flight Differences at Same Level
Duty Equality	0-10	Duty Differences at Same Level

Table 8: Evaluation Measures Range and Unit Table

3.2.4 Step 4: Create Value Functions

The previous step collects all evaluation measures for the value hierarchy and decides on the ranges and units of these measures. As can be seen in Table 8, the measures have different ranges and units. However, in order to get an overall score from the structure, we need to have similar units and ranges for each evaluation measure. The Single Dimensional Value Function (SDVF) changes the different ranges and units to similar ones. It uses a zero to one range and gives a score that can be thought of as a ratio of satisfaction of the values. There are two classes of SDVF. The first one is continuous and converts an infinite number of inputs into the [0, 1] range. The other class uses categorical scales, and it is called a discrete SDVF. If the number of possible inputs is

small and certain, the discrete SDVF is more suitable. In this research, ten out of the twelve value functions are created using exponential functions as continuous SDVFs.

$$v_i(x_i) = \begin{cases} \dfrac{1-\exp[-(x_i - x_i^L)/\rho_i]}{1-\exp[-(x_i^H - x_i^L)/\rho_i]}, \rho_i \neq \infty \\ \hline \dfrac{x_i - x_i^L}{x_i^H - x_i^L}, otherwise \end{cases}$$

(2)

Equation (2) is the equation for monotonically increasing value functions. Monotonically increasing means the value increases as the score increases and can never be less than a previous value (Kirkwood, 1997).

$$v_i(x_i) = \begin{cases} \dfrac{1-\exp[-(x_i^H - x_i)/\rho_i]}{1-\exp[-(x_i^H - x_i^L)/\rho_i]}, \rho_i \neq \infty \\ \hline \dfrac{x_i^H - x_i}{x_i^H - x_i^L}, otherwise \end{cases}$$

(3)

Equation (3) is the equation for monotonically decreasing value functions (Kirkwood, 1997).

Where:

$v_i(x_i)$ = the exponential single dimensional value function for alternative x on measure i

x_i = score for alternative x on measure i

x_i^H = the upper bound for alternative x on measure i

x_i^L = the lower bound for alternative x on measure i

ρ_i = exponential constant for measure i

The value functions in this research are constructed with the help of DMs and SMEs from the squadrons. A computer software program is used to facilitate the process. This research uses the Hierarchy Builder 2.0 software program which helps build the value hierarchy at every step of value focused thinking (Weir J. , 2008).

3.2.4.1 Value Functions for Evaluation of Readiness

Under the readiness value there are two evaluation measures named currency and wanted readiness. Both of them have monotonically decreasing piecewise exponential value functions.

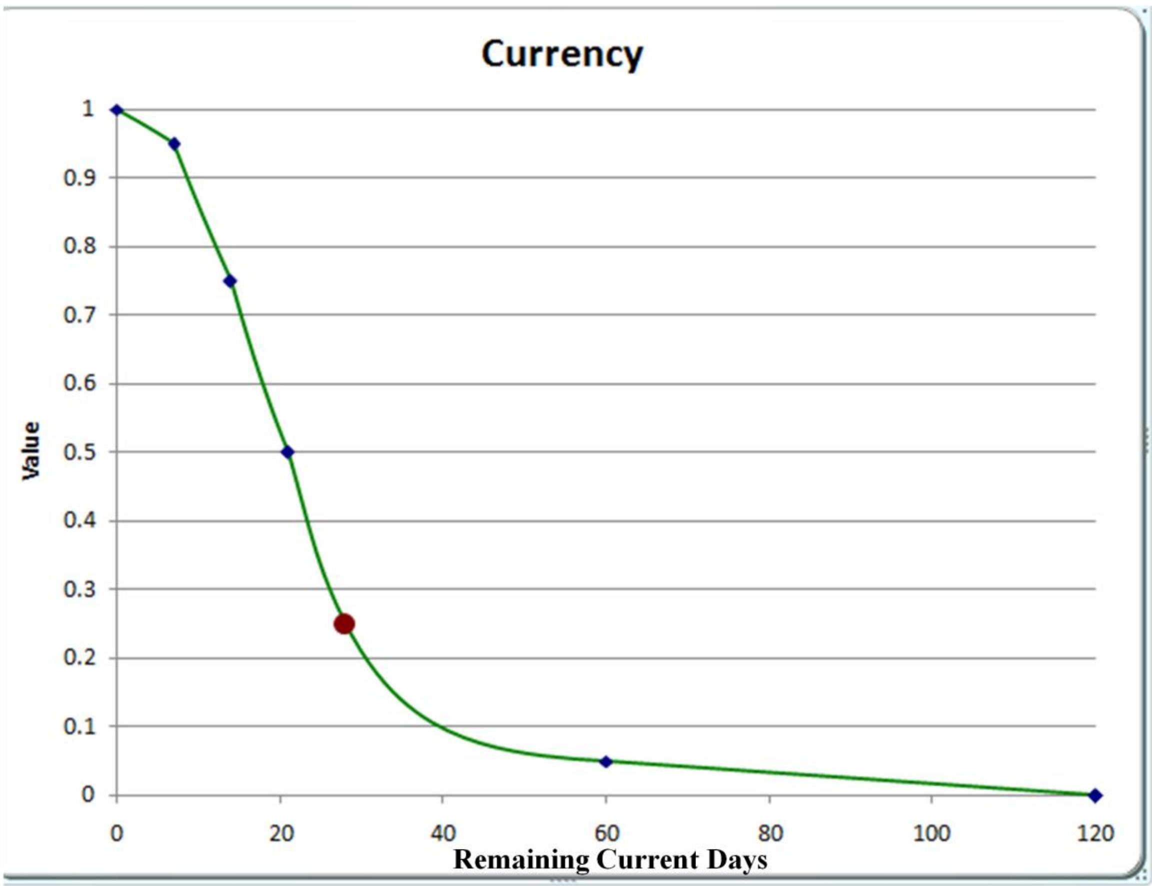


Figure 10: Value Function for Currency

Figure 10 shows the value function for currency which has a range of [0,120] on the X axis and [0, 1] on the Y axis. Using this function, the currency measure's range is converted to the general range of a value model. DMs are asked to decide on several critical numbers of days while they are scheduling and thinking about currency. According to the DMs, the critical points are 7, 14, 21, 28 and 60 days before being non-current. So, one week before is the most critical time to schedule a pilot to a mission because schedulers prepare weekly schedules. The other critical days are also for reminding schedulers that the last days are coming before becoming non-current. Sixty days is the point in time that means a specific pilot does not need the mission until sixty days has passed after his last flight for that certain mission.

The wanted readiness part of the same value is converted with a similar value function. All value functions used and the spreadsheets with the necessary calculations are presented in Appendix B.

3.2.4.2 Value Functions for Evaluation of Frequency

The frequency value is evaluated by four measures and these measures have similar value functions. As an example, a yearly scheme is selected and introduced here.

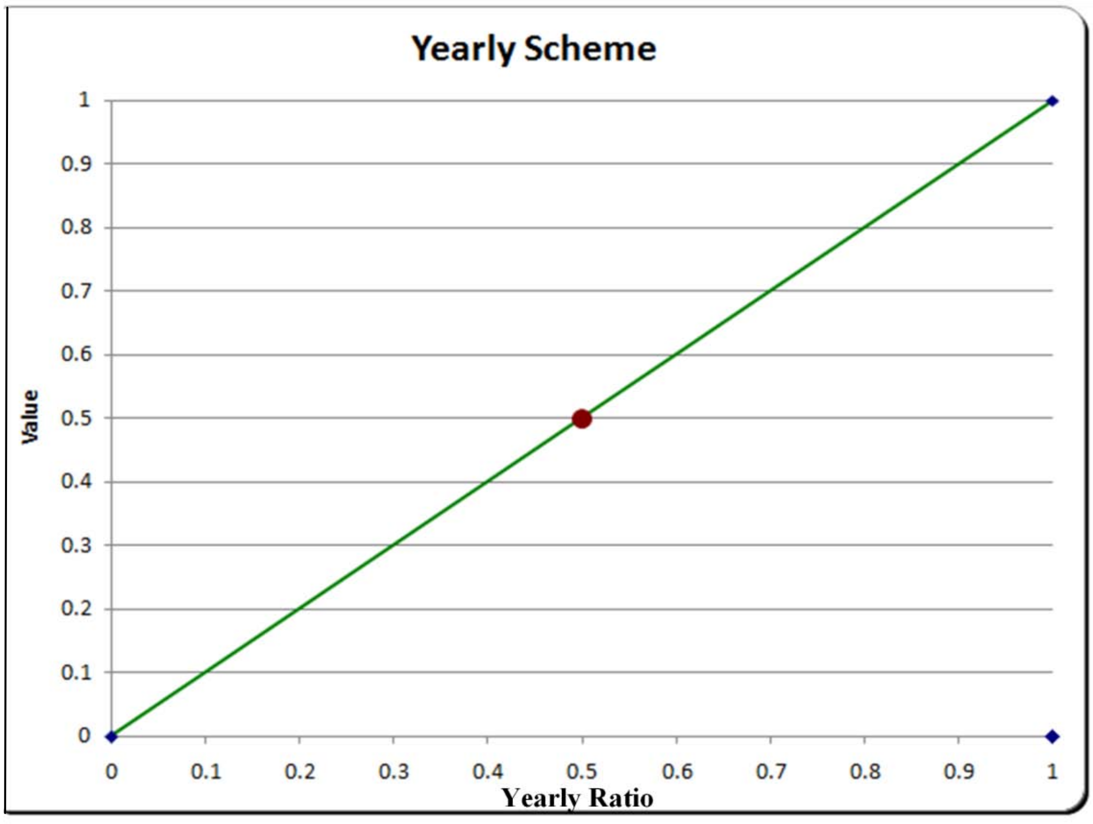


Figure 11: Value Function for Yearly Scheme

The previous paragraphs discussed the yearly scheme and how it is calculated. After calculation of the yearly scheme and yearly ratio by the respective spreadsheet of a pilot, the continuous SDVF is used to get the value of the yearly scheme. DMs agreed that all percentages of yearly ratio should be the same as the value. For instance a yearly ratio of 0.5 gives a 0.5 as the yearly scheme value. The rest of the evaluation measures' SDVFs for frequency are formed similarly. All value functions, spreadsheets and necessary calculations are presented in Appendix B.

3.2.4.3 Value Functions for Evaluation of Improvement

The Improvement value introduces two evaluation measures. They are career and personal need. After the DMs are solicited, SDVFs for these measures showed up as categorical scaled value functions. As an example, the personal need part is shown here.

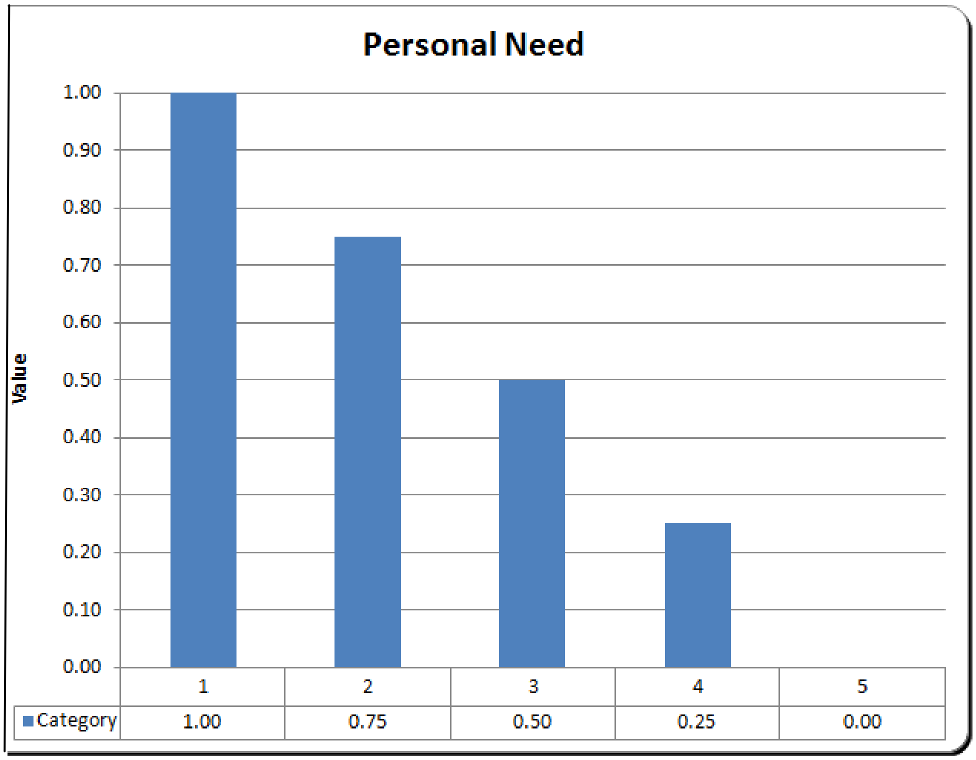


Figure 12: Value Function for Personal Need

Figure 12 shows the SDVF for personal need, and it is a discrete value function containing five categories. As stated in the previous paragraphs, the personal need spreadsheet is created by the training section of squadrons, and it keeps the grades of the last flights related to the specific pilot. After evaluation of the flight, leaders or instructors enter the grades into the spreadsheet and the grades are inputs for the personal need evaluation measure of the improvement value. For example if a pilot receives a four from his/her last flight of a certain mission, he/she gets 0.25 as a score for personal need. This

means he or she does not need to fly this certain mission for a while. The Career part is almost the same. All value functions, spreadsheets and necessary calculations are presented in Appendix B.

3.2.4.4 Value Functions for Evaluation of Motivation

The motivation value has four evaluation measures; permission, yearly equality, monthly equality and duty equality. The first three measures' SDVFs are monotonically increasing and similar to each other when calculating the values. Due to this similarity, monthly equality is shown as an example of the three value functions.

The following figure is the exponential function of monthly equality. According to the DMs' opinions, there are two critical points in this. The range for monthly equality is [0, 8] and the unit is the difference of flight count at the same level of experience. DMs and pilots agreed that there is no significant problem with the differences between zero and two, but after that point, the importance of the difference rises quickly until the point of difference in the flight count is six.

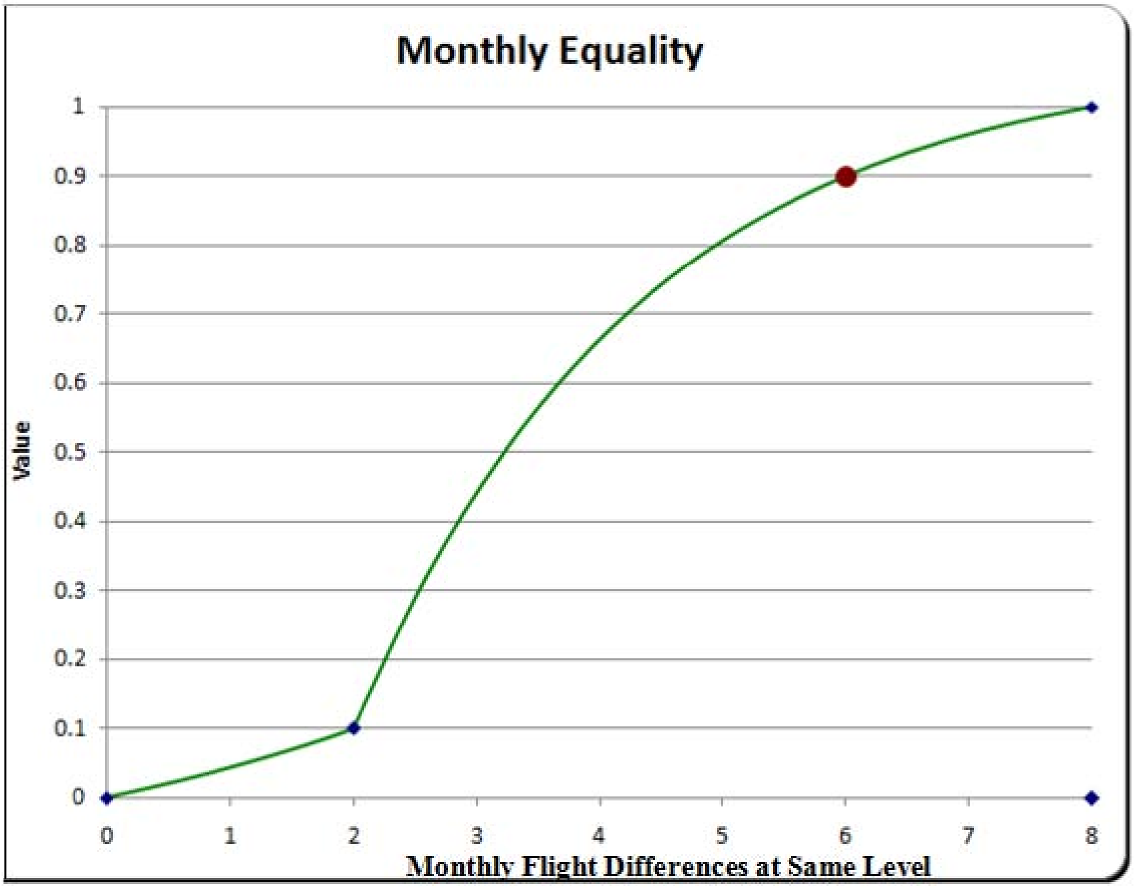


Figure 13: Value Function of Monthly Equality

DMs and pilots are asked to evaluate the points two and six to get the values shown in Figure 13.

Another evaluation measure for motivation is duty equality. This measure's SDVF is a decreasing continuous function. The spreadsheet for tracking the equality among pilots keeps the total amount of duties that every pilot held in this flight year and then calculates the differences of duty counts between every pilot and the pilot at same experience level who was on duty the most. According to this number, the scores for the duty equality part are acquired.

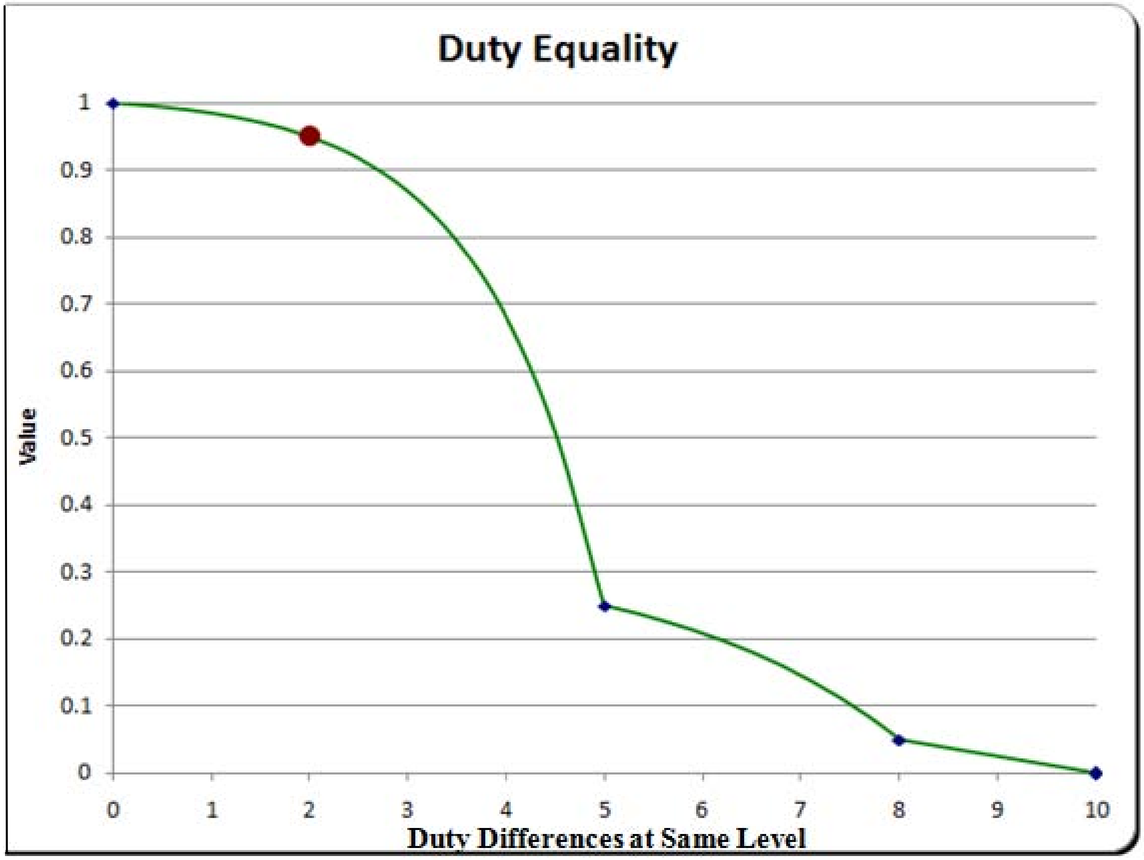


Figure 14: Value Function for Duty Equality

The critical points are determined with respect to the pilots' point of view. According to them, the value decreases quickly as the differences decrease to five. Then from five to eight, the values of differences decrease less quickly. Finally the last point is ten because all of the pilots agreed that differences higher than ten do not change motivation. The ratios are solicited from pilots and the Y axis is created with the help of their inputs.

Two of the four evaluation measures for motivation are shown in this part as examples. However, all value functions, spreadsheets and necessary calculations are presented in Appendix B.

3.2.5 Step 5: Weight Value Hierarchy

At this step, building the value hierarchy is finished after prioritizing and ordering the values by the preferences of the DM. Because the values do not have the same importance, they must be weighted in order to sum the scores according to their priorities. There are two ways to weight the value hierarchy as mentioned in Chapter 2. In this research, local weighting is used due to large number of branches and then the four branches are weighted individually. With the help of the Hierarchy Builder 2.0 software program, weights are decided in accordance with the DMs' view. This research uses the Analytic Hierarchy Process (AHP) method in order to obtain the weights. The following figures introduce how the AHP method gives the weights for the motivation value with the help of Hierarchy Builder (Weir J. , 2008). The AHP method has DMs give their preferences between two values' importance as a number scaled one to nine. The number scale is given a meaning by the degree of favorability of one value over another. Figure 15 displays the AHP weightings of the DM for this research in terms of the motivation Value.

Figure 15: Pairwise Comparisons of the Motivation Value Evaluation Measures

Permission is quite slightly favored compared to yearly equality and it is slightly favor compared to monthly equality. According to pilots, duty equality is more important than permission but the importance difference is really small. Pilots are asked about the comparison of importance between monthly and yearly equality of flight counts and the answers are generally in direction of yearly equality but the difference is not even slightly, so it is scaled as two. Pilots admit that the duty equality looks weightier than yearly equality but the degree of priority is nearly the same. At last, duty equality is said to be slightly favor in comparison to monthly equality. After all comparisons finish, the program gives the weights in accordance with assessments above.

Measure Name	Local Weight
Permission	0.293
Yearly Equality	0.185
Monthly Equality	0.107
Duty Equality	0.415

Table 9: Motivation Branch Local Weights

Table 9 reveals the local weights for the motivation value branch. Before continuing for the other branches, DMs are solicited for their satisfaction about the local weights and if they agree with the outputs, so this may be an iterative process. Finally, all weights are gathered and converted to global weights. The following table shows all twelve measures and their weights. According to their weights, currency is the most important and monthly equality is the least important measure in the value hierarchy.

Measures	Weights
Currency	0.382
Yearly Scheme	0.170
Wanted Readiness	0.127
Monthly Scheme	0.097
Career	0.088
Daily Wanted	0.039
Personal Need	0.022
Duty Equality	0.022
Weekly Wanted	0.020
Permission	0.015
Yearly Equality	0.010
Monthly Equality	0.006

Table 10: Global Weights of Value Hierarchy

Weights calculated with the help of DMs' opinions are used for evaluating alternatives and obtaining the overall value of the alternatives.

3.2.6 Step 6: Alternative Generation

The alternative generation step introduces the task of collecting all possible pilot-mission matches in this research. Because fighter squadrons have approximately 30 pilots and 50 missions, the count for possible matches will be 1500. The following table shows some examples of generated pilot-mission matches.

Alternative Name
P1-M45
P10-M46
P21-M47
P32-M48
P5-M49
P50-M26
P43-M50
P2-M45
P2-M46
P2-M47
P2-M48

Table 11: An Example Table of Possible Matches

3.2.6 Step 7: Alternative Scoring

The only step remaining before analyzing alternatives is finding data related to the alternatives. A spreadsheet is used to automatically transfer the data from all pilots' track files. The following table has sample matches and needed inputs for the alternatives.

Alternative Name	Currency	W.Readiness	Y. Scheme	M. Scheme	W. Wanted	D. Wanted
P1-M1	110	100	0.70	0.40	0.3	0.33
P2-M4	99	90	0.50	0.30	0.6	0.66
P15-M3	87	87	0.40	0.65	0.7	0.33
P10-M4	5	5	0.90	0.31	0.3	0.66
P22-M5	56	45	0.30	0.44	0.1	0.33

Table 12: An Example of Inputs Spreadsheet for Sample Alternatives Part-1

Alternative Name	Career	P. Need	Permission	Y. Equality	M. Equality	D.Equality
P1-M1	1	1	1	15	2	0
P2-M4	0	2	0.55	1	4	10
P15-M3	2	3	0	30	6	2
P10-M4	0	4	0.33	0	7	6
P22-M5	1	5	0.1	24	8	8

Table 13: An Example of Inputs Spreadsheet for Sample Alternatives Part-2

3.3 Summary

In this chapter, the definitions and specifications of flight scheduling in fighter squadrons was stated and the VFT method was implemented for modeling solution to this problem. In the next chapter, the model is verified and validated.

4. RESULTS AND ANALYSIS

This chapter contains verification and validation for the research model. This decision model for the pilot-mission assignment is verified and validated using the deterministic and sensitivity analysis part of VFT and the DM's feedback.

4.1 Verification of the Research Model

In this research, the Hierarchy Builder 2.0 software program is used for building the decision model. After the construction steps, in order to calculate the scores of evaluation measures and overall scores, the same program is used but some embellishments were made for the purpose of accelerating the analysis steps of VFT. This verification part considers these new additions made by the author. However, one sample evaluation measure is calculated manually to verify the software program's model first.

The sample evaluation measure selected is currency. As mentioned in Chapter 3, currency has a monotonically decreasing function. In this part of the verification section, some numbers of days are taken as sample inputs and then scores of the currency measure are evaluated manually and by the model to compare.

Equation (3) is used to calculate the value of a point in a monotonically decreasing function. So, currency scores are graded by this function. Nevertheless, we do not know all the entries in that formula. We need to calculate the ρ value which is the exponential constant. Equation (3) assumes that the highest entry gives zero and the lowest entry gives one. However, most of the SDVF created in this research are made of several parts that do not start with zero and end with one. Due to this fact, the formula must be changed. First, to scale the value function, the difference between two extreme

points' scores is multiplied with it and then the point where the lowest score of value function occurs is added to this function. Therefore, the new formula is:

$$V(x) = \frac{1-e^{-\frac{x^H - x}{\rho}}}{1-e^{-\frac{x^H - x^L}{\rho}}} \times [V(x^H) - V(x^L)] + V(x^L) \qquad \textbf{\textit{(5)}}$$

With the currency SDVF, the value of 28 days and 21 and 60 days is solicited from the DM. The score of 28 days is 0.25 while 21 and 60 were 0.5 and 0.05, respectively. Using these values, the ρ value of this part of the function is calculated. Then this ρ value is used to calculate values of other days between 21 and 60. Using Excel and Equation (5), the ρ value of the scaled function was obtained. At first, Excel Goal Seek is used to approximate the ρ value and then around this value a local search is made to get the exact value of 28 days. The following table shows the ρ values and the value of 28 days using the corresponding ρ value.

	RHO	V(28)
1	-8.7913487739407200	0.25000000000001300
2	-8.7913487739406200	0.25000000000001200
3	-8.7913487739405200	0.25000000000001000
4	-8.7913487739404200	0.25000000000000800
5	-8.7913487739403200	0.25000000000000600
6	-8.7913487739402200	0.25000000000000500
7	-8.7913487739401200	0.25000000000000300
8	***-8.7913487739400200***	***0.25000000000000100***
9	***-8.7913487739399200***	***0.24999999999999900***
10	-8.7913487739398200	0.24999999999999800

Table 14: Local Search for Rho Value

As can be seen from Table 14, the two ρ values that are the closest scores for 28 days are the 8th or 9th , but we do not need that much accuracy for this research. After obtaining the ρ value, the following currency scores were calculated manually and by the model.

Number of Days	Currency Scores-1	Currency Scores-2	Differences
21	0.5	0.5	0
25	0.33353249686403600	0.33362786960279600	-0.00009537273875954
30	0.20820785604108200	0.20832609176335700	-0.00011823572227548
35	0.13724429267665000	0.13734408217385400	-0.00009978949720432
40	0.09706203248975020	0.09713359376545740	-0.00007156127570715
45	0.07430931324655370	0.07435481661625520	-0.00004550336970152
50	0.06142586093322400	0.06145090251446420	-0.00002504158124018
55	0.05413076175251970	0.05414098424906550	-0.00001022249654578
60	0.05	0.05	0
		Average Difference	-0.00005174740904822

Table 15: Currency Scores Calculated By Manual versus By Model

The Currency Scores-1 column gives the scores calculated manually and the Currency Scores-2 column shows the scores calculated by the software. The differences are small and the average of the differences is not significant for this research problem. More accurate ρ values could be used, but it is not necessary to use five digits or more in this model. This model aims to construct a big picture for the DM, so using five digits or more would make this picture more complicated, not less.

To continue the verification, ten alternatives were prepared randomly. All evaluation measures' inputs were obtained with the help of the Excel RandBetween function. The following tables show the results measure by measure. They contain a column for inputs, a column for the scores by this research's model (i.e. currency-1) and another column for the scores by the software (i.e. currency-2).

Alternative Name	Currency	Currency-1	Currency-2	Wanted Readiness	Wanted Readiness-1	Wanted Readiness-2
1	43	0.081952021	0.081952021	24	0.368157198	0.368157198
2	39	0.103458454	0.103458454	34	0.148167262	0.148167262
3	47	0.06830238	0.06830238	36	0.127071134	0.127071134
4	75	0.037518744	0.037518744	54	0.055249201	0.055249201
5	50	0.061450903	0.061450903	17	0.630447245	0.630447245
6	68	0.043344883	0.043344883	62	0.048336017	0.048336017
7	109	0.009181645	0.009181645	44	0.077773951	0.077773951
8	58	0.051381106	0.051381106	45	0.074206644	0.074206644
9	35	0.137344082	0.137344082	27	0.27448839	0.27448839
10	50	0.061450903	0.061450903	38	0.11027426	0.11027426

Table 16: Verification of Readiness Part

Table 16 shows the evaluation measure calculations of the readiness value with two methods. According to the scores, it is easily seen that the two methods give the same results.

Alternative Name	Yearly Scheme	Yearly Scheme-1	Yearly Scheme-2	Monthly Scheme	Monthly Scheme-1	Monthly Scheme-2
1	0.24	0.24	0.240608351	0.19	0.19	0.190513353
2	0.27	0.27	0.270657335	0.69	0.69	0.690712698
3	0.93	0.93	0.930216793	0.78	0.78	0.780571644
4	0.83	0.83	0.830469988	0.99	0.99	0.990032964
5	0.12	0.12	0.120352297	0.01	0.01	0.010033036
6	0.3	0.3	0.300700311	0.74	0.74	0.740640991
7	0.38	0.38	0.380785542	0.46	0.46	0.460828073
8	0.26	0.26	0.260641675	0.5	0.5	0.500833333
9	0.64	0.64	0.64076776	0.9	0.9	0.900299733
10	0.63	0.63	0.630776775	0.68	0.68	0.680725043

Table 17: Verification of Frequency Part-1

Alternative Name	Weekly Wanted	Weekly Wanted-1	Weekly Wanted-2	Daily Wanted	Daily Wanted-1	Daily Wanted-2
1	0.45	0.45	0.450825091	0.3	0.3	0.300700311
2	0.9	0.9	0.900299733	0.42	0.42	0.420812144
3	0.36	0.36	0.360768238	0.97	0.97	0.970096899
4	0.51	0.51	0.510832981	0.3	0.3	0.300700311
5	0.81	0.81	0.810512646	0.2	0.2	0.200533689
6	0.1	0.1	0.100300267	0.87	0.87	0.87037669
7	0.47	0.47	0.470830388	0.05	0.05	0.050158492
8	0.63	0.63	0.630776775	0.7	0.7	0.700699688
9	0.62	0.62	0.620785123	0.39	0.39	0.390793193
10	0.93	0.93	0.930216793	0.82	0.82	0.82049165

Table 18: Verification of Frequency Part-2

Table 17 and Table 18 compare the results for the frequency part of the value model. Considering the scores from the two models, there are slight differences on all alternatives. This slight change is based on the different processes of determining the ρ values. The differences in these frequency calculations are shown in the example below.

YEARLY FLIGHT	YEARLY SCHEME	YEARLY PRESENCE
19	120	173
YEARLY RATIO		
0.583815029		
YEARLY FLIGHT	YEARLY SCHEME	YEARLY PRESENCE
Input	Input	Input
YEARLY RATIO		
IF((Yearly Scheme-Yearly Flight)/Yearly Presence>0,IF((Yearly Scheme-Yearly Flight)/Yearly Presence<1,(Yearly Scheme-Yearly Flight)/Yearly Presence,1),0)		

Table 19: An Example of Yearly Scheme Calculation

Table 19 is an example of the yearly scheme calculation spreadsheet. The top part has the inputs from the SMEs and the lower part calculates the ratio according to the formula that Table 19 shows. The difference between models starts from this step on. The software uses the calculated yearly ratio as an input and gives an output according to the SDVF. The new model uses the yearly ratio as the score of yearly scheme directly. To get rid of an unnecessary step in the process, the ratios are accepted as outputs of frequency evaluations.

Furthermore, Hierarchy Builder 2.0 uses an approximation method for finding ρ values. Because the SDVFs of the frequency evaluation measures are linear functions, the software program must use infinity as its ρ value. Instead, it tries to use a large number in order to simulate infinity so the results for the scores from the frequency are different from the real outputs.

Alternative Name	Career	Career-1	Career-2	Personal Need	Personal Need-1	Personal Need-2
1	0	0	0	3	0.5	0.5
2	1	0.75	0.75	1	1	1
3	0	0	0	4	0.25	0.25
4	2	1	1	2	0.75	0.75
5	1	0.75	0.75	1	1	1
6	0	0	0	1	1	1
7	0	0	0	3	0.5	0.5
8	0	0	0	4	0.25	0.25
9	1	0.75	0.75	2	0.75	0.75
10	0	0	0	1	1	1

Table 20: Verification of Improvement Part

Table 20 verifies that there is no difference between the two evaluation models in terms of the improvement part calculations.

Alternative Name	Permission	Permission-1	Permission-2	Yearly Equality	Yearly Equality-1	Yearly Equality-2
1	0.83	0.83	0.830469988	7	0.310593114	0.310593114
2	0.27	0.27	0.270657335	3	0.057767028	0.057767028
3	0.91	0.91	0.910272751	17	0.834528359	0.834528359
4	0.04	0.04	0.040128131	26	0.973983941	0.973983941
5	0.55	0.55	0.550824908	2	0.037794401	0.037794401
6	0.42	0.42	0.420812144	11	0.600722701	0.600722701
7	0.96	0.96	0.960127869	15	0.775343985	0.775343985
8	0.85	0.85	0.850424669	10	0.541364125	0.541364125
9	0.4	0.4	0.400800177	0	0	0
10	0.29	0.29	0.290686653	23	0.943700732	0.943700732

Table 21: Verification of Motivation Part-1

Alternative Name	Monthly Equality	Monthly Equality-1	Monthly Equality-2	Duty Equality	Duty Equality-1	Duty Equality-2
1	8	1	1	4	0.682034573	0.682034573
2	8	1	1	7	0.145621521	0.145621521
3	1	0.043687038	0.043687038	7	0.145621521	0.145621521
4	6	0.900118335	0.900118335	4	0.682034573	0.682034573
5	3	0.441409553	0.441409553	8	0.05	0.05
6	0	0	0	7	0.145621521	0.145621521
7	6	0.900118335	0.900118335	5	0.25	0.25
8	6	0.900118335	0.900118335	2	0.949857834	0.949857834
9	4	0.662985592	0.662985592	8	0.05	0.05
10	8	1	1	1	0.984856436	0.984856436

Table 22: Verification of Motivation Part-2

Table 21 and Table 22 help investigate the motivation part of the value model. The only difference is between the Permission-1 and Permission-2 columns. These insignificant changes depend on the same reasoning as the frequency part calculations' differences discussed above. Hence, an unnecessary step is omitted in the process once again, and the new model ends with approximately the same results as the software calculates.

Alternative Name	Overall-1	Overall-2	Differences
1	0.206147928	0.206353156	-0.000205228
2	0.30854901	0.30877854	-0.00022953
3	0.353214507	0.353330846	-0.000116339
4	0.416441521	0.416571285	-0.000129764
5	0.25049049	0.250597921	-0.000107431
6	0.219879931	0.220095005	-0.000215074
7	0.178536828	0.178776266	-0.000239438
8	0.212506489	0.212746846	-0.000240357
9	0.405898459	0.406117921	-0.000219462
10	0.325420604	0.325657743	-0.00023714
		Average Difference	-0.000193976

Table 23: Verification of Overall Scores

Table 23 shows that there are only small differences in the fourth decimal place of the scores. Besides, the average difference verifies that there is no significant difference considering this research's goals.

4.2 Validation of the Research Model

For the purpose of validating the decision model of the assignment problem, this research uses four steps:

1. Creating ten different groups of five assignment alternatives.
2. Soliciting the DM to order these alternatives in terms of his preferences.
3. Using the value model to order these alternatives with the help of the deterministic analysis part of VFT.
4. Comparing the results

After comparing the results, the model is valid if there is no difference. But if there is a difference, the validation process involves two steps. First, using sensitivity analysis for minor differences to try and determine if the weights are correct. While doing

this, the DM may change his weights after seeing the structured values of the model. The other way is for large differences to determine if the model is missing some evaluation criterion. Hence, the model must be changed with the help of the DM's feedbacks and then the validation starts again.

The first step of the validation process is preparing randomized alternatives. In this step, ten groups of five alternatives are created with the Excel RandBetween function. Furthermore, these groups were designed in several difficulty levels in order to begin solving simple assignment problems and then harder ones. For instance, there are many fixed measures in the simple problems so the DM has to consider only two or three measures or values to rank the five alternatives. The validation alternatives are also constructed in two types. The first type takes a pilot and considers the available mission matches for that pilot. However, the second type chooses five different pilots and five different available missions to assign these pilots, respectively.

4.2.1 Comparing Mission Assignments for a Specific Pilot

In this part, five problems were created. The first problem contains currency and wanted readiness data that were randomly selected. The other data needed for these five assignments were chosen as fixed entries.

Missions	Current Days	Wanted Days	Currency Left	Wanted Left
M-1	120	30	67	0
M-2	90	60	67	37
M-3	60	60	44	44
M-4	45	30	36	21
M-5	30	21	28	19

Table 24: Problem-1 Inputs

DM's Order	Model's Order	Overall Scores From Model
M-1	M-5	0.358
M-5	M-1	0.335
M-4	M-4	0.303
M-3	M-3	0.231
M-2	M-2	0.223

Table 25: Solutions for Problem-1

The DM and model ordered the alternatives according to the related data on Table 24. Table 25 shows the evaluations by the two sources. Since there is a difference between the two solutions, this model may not be valid. However, running sensitivity analysis with the software, the DM was able to see the reason for the difference. The following figures show one way sensitivity analysis on the currency and wanted readiness measures.

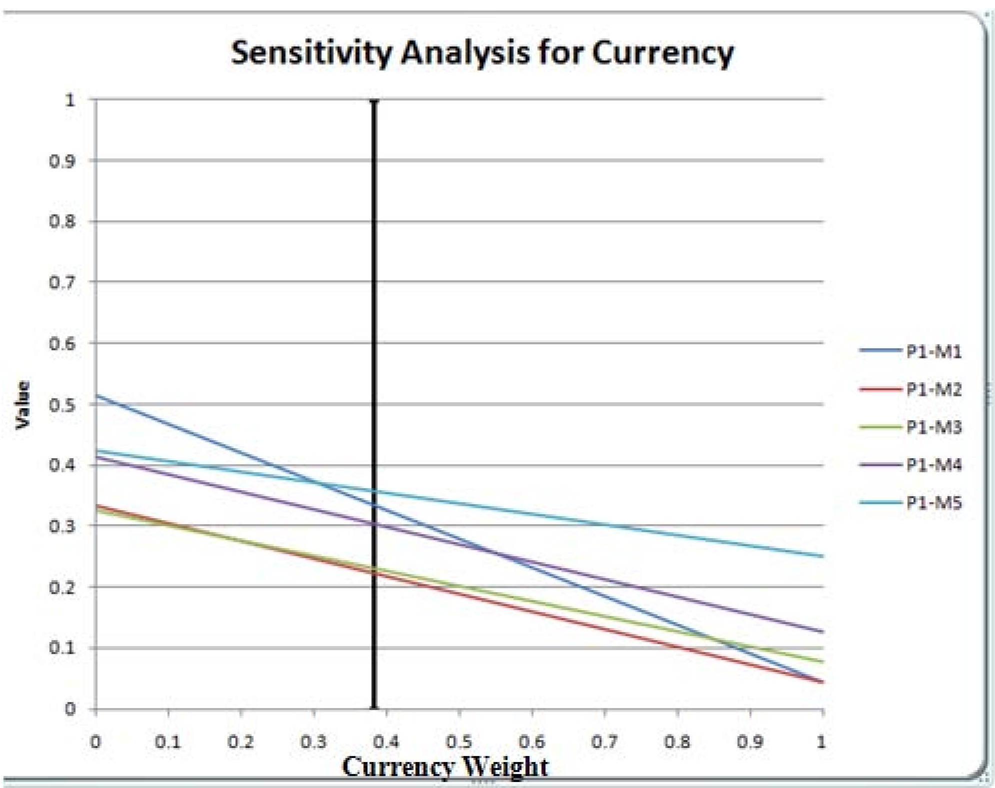


Figure 16: One Way Sensitivity Analysis for Currency

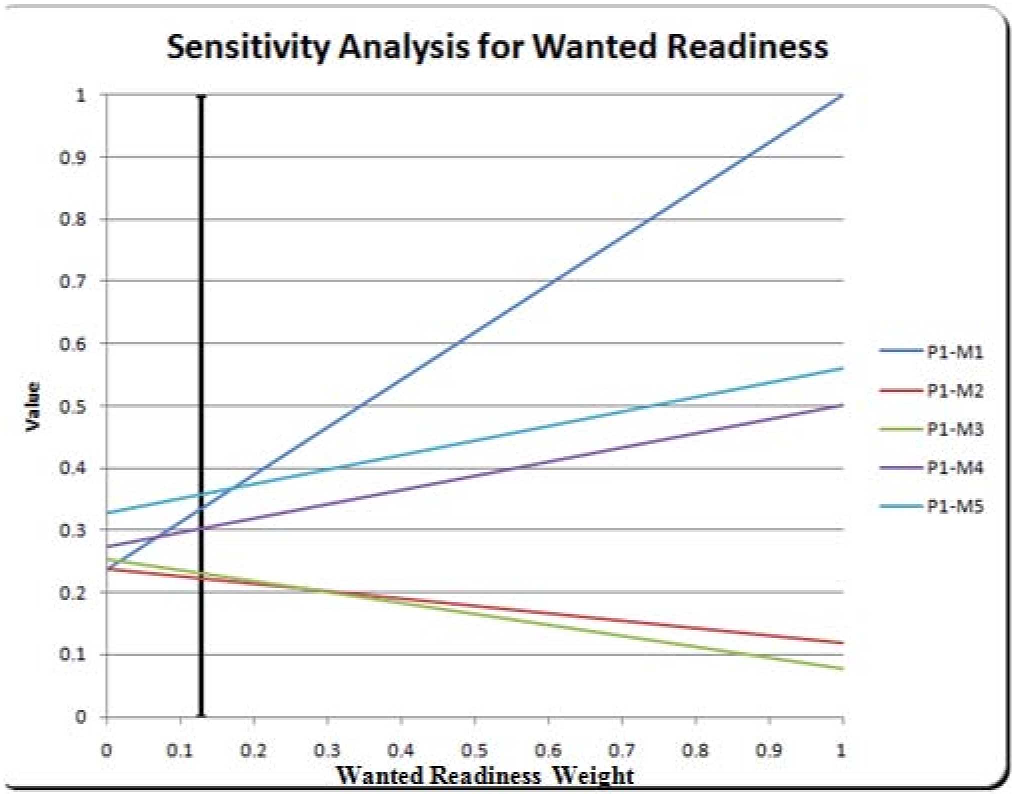


Figure 17: One Way Sensitivity Analysis for Wanted Readiness

Using the results from the sensitivity analysis for currency and wanted readiness, the DM is asked if lowering the weight of currency from 0.382 to approximately 0.3 or increasing the weight of wanted readiness from 0.127 to almost 0.2 is reasonable. The DM did not want to change the weights and accepted the model ordering of the alternatives.

The next problem is similar to Problem-1 to be sure about the currency and wanted readiness values tradeoffs. The following table shows the random inputs for Problem-2.

Missions	Current Days	Wanted Days	Currency Left	Wanted Left
M-1	120	30	67	0
M-2	90	60	38	8
M-3	90	90	39	39
M-4	60	60	10	10
M-5	60	30	11	0

Table 26: Inputs for Problem-2

The DM was solicited after being shown Table 26. Then the model was run for these inputs. Other inputs were selected as the same for all mission types.

DM's Order	Model's Order	Overall Scores From Model
M-5	M-5	0.636
M-4	M-4	0.629
M-2	M-2	0.350
M-1	M-1	0.335
M-3	M-3	0.244

Table 27: Solutions for Problem-2

According to the DM and the model, the solutions are exactly the same so that the tradeoff between currency and wanted readiness is answered correctly by the model.

Problem-3 was prepared to see the priorities considering three measures, currency, wanted readiness and personal need.

Missions	Current Days	Wanted Days	Currency Left	Wanted Left	Personal Need
M-1	120	37	88	5	4
M-2	120	53	98	31	1
M-3	120	36	118	34	4
M-4	120	37	67	0	4
M-5	120	38	96	14	5

Table 28: Inputs for Problem-3

DM's Order	Model's Order	Overall Scores From Model
M-4	M-4	0.341
M-1	M-1	0.329
M-5	M-5	0.294
M-2	M-2	0.244
M-3	M-3	0.216

Table 29: Solutions for Problem-3

Due to the increase in the count of measures to be considered, the DM needed more time than the previous problems. However, the solutions are the same and thus Table 29 validates the model so far.

The next problem tries to introduce the DM to Personal Need versus Career. It uses consecutive numbers for Currency and Wanted Readiness entries in order to simplify the problem for the DM. The other eight evaluation measures were assumed to be constant for all missions.

Missions	Currency Left	Wanted Left	Personal Need	Career
M-1	88	88	4	1
M-2	89	89	1	1
M-3	90	90	4	1
M-4	91	91	4	0
M-5	92	92	5	2

Table 30: Inputs for Problem-4

While soliciting the DM for the solution to Problem-4, he had difficulty deciding between M-3 and M-5. The following table verifies the confusion and the difference between the DM's and model's solution.

DM's Order	Model's Order	Overall Scores From Model
M-3	M-5	0.302
M-5	M-3	0.292
M-1	M-1	0.287
M-2	M-2	0.270
M-4	M-4	0.220

Table 31: Solutions for Problem-4

As far as overall scores concerned, it is hard to decide the order between any alternatives because the numbers are similar. However, sensitivity analysis can be done in order to clear up the confusion. The following figures reveal the sensitivity of results on the change of Personal Need or Career weights.

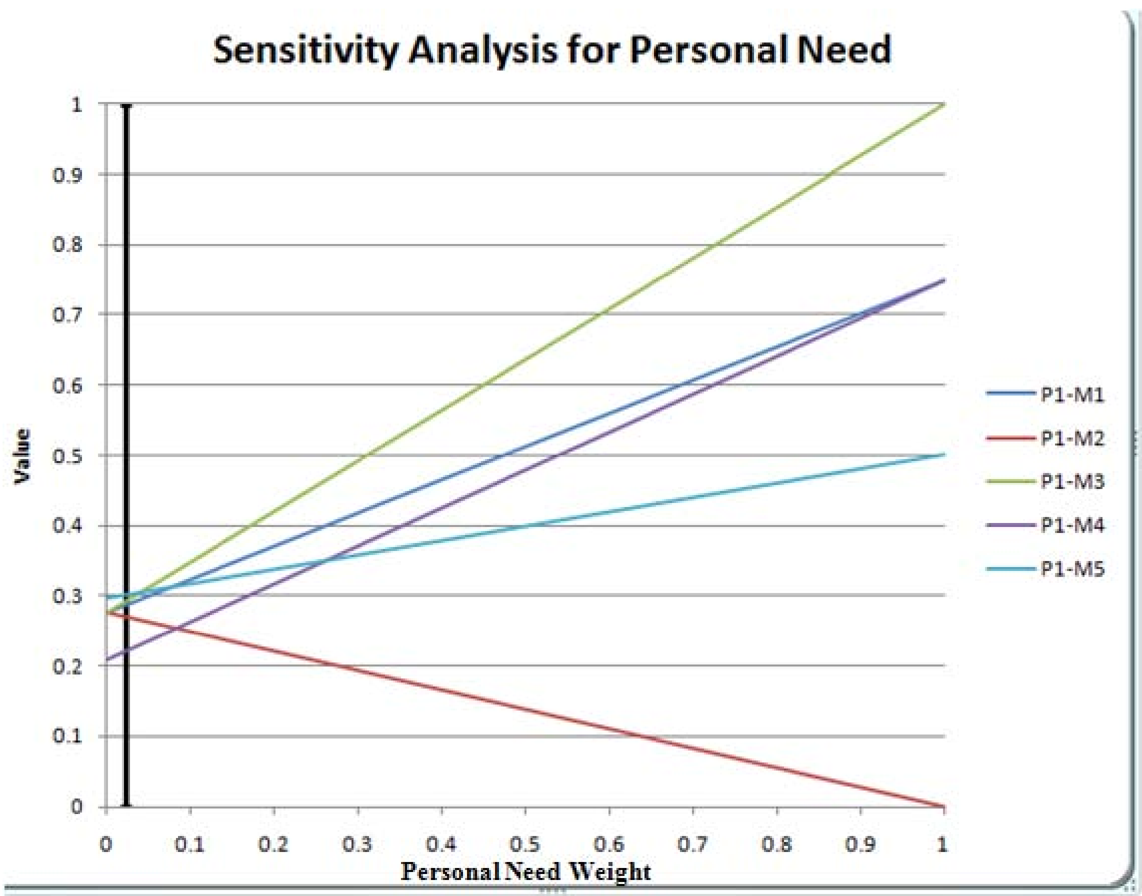


Figure 18: One Way Sensitivity Analysis for Personal Need

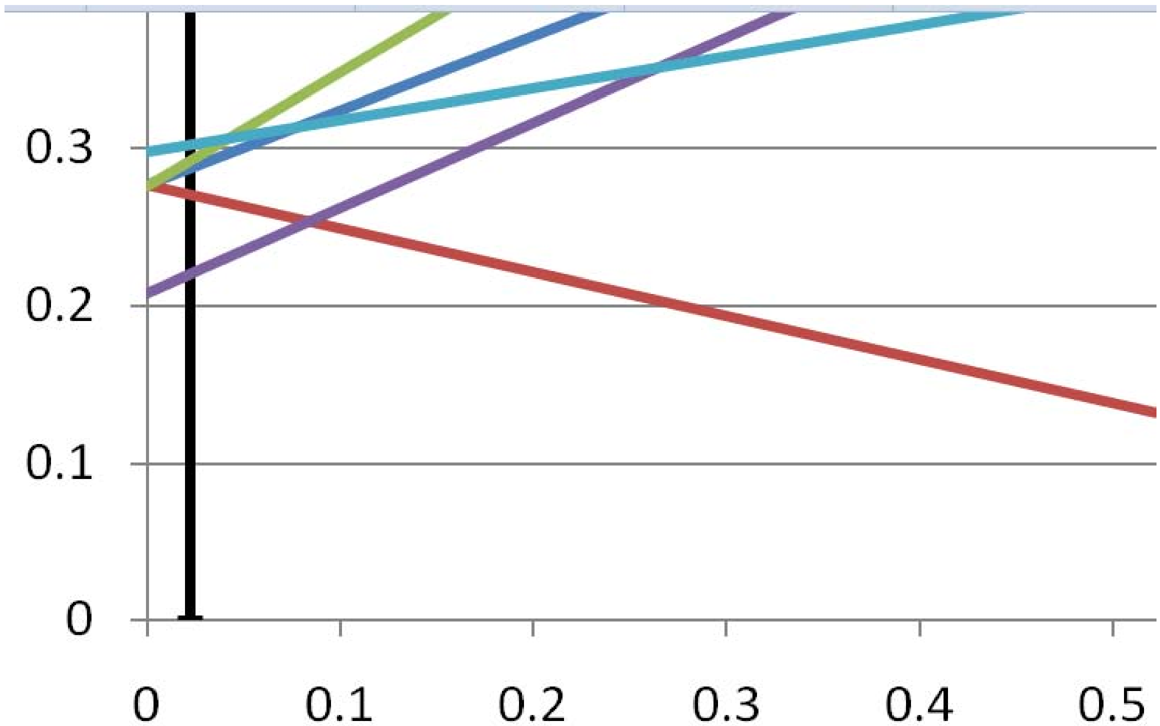


Figure 19: Zoomed View for Figure-18

Figure 18 and Figure 19 demonstrate why a decision between M-1, M-3 and M-5 is difficult. With a slight change in weight of Personal Need, every order is possible between these three missions.

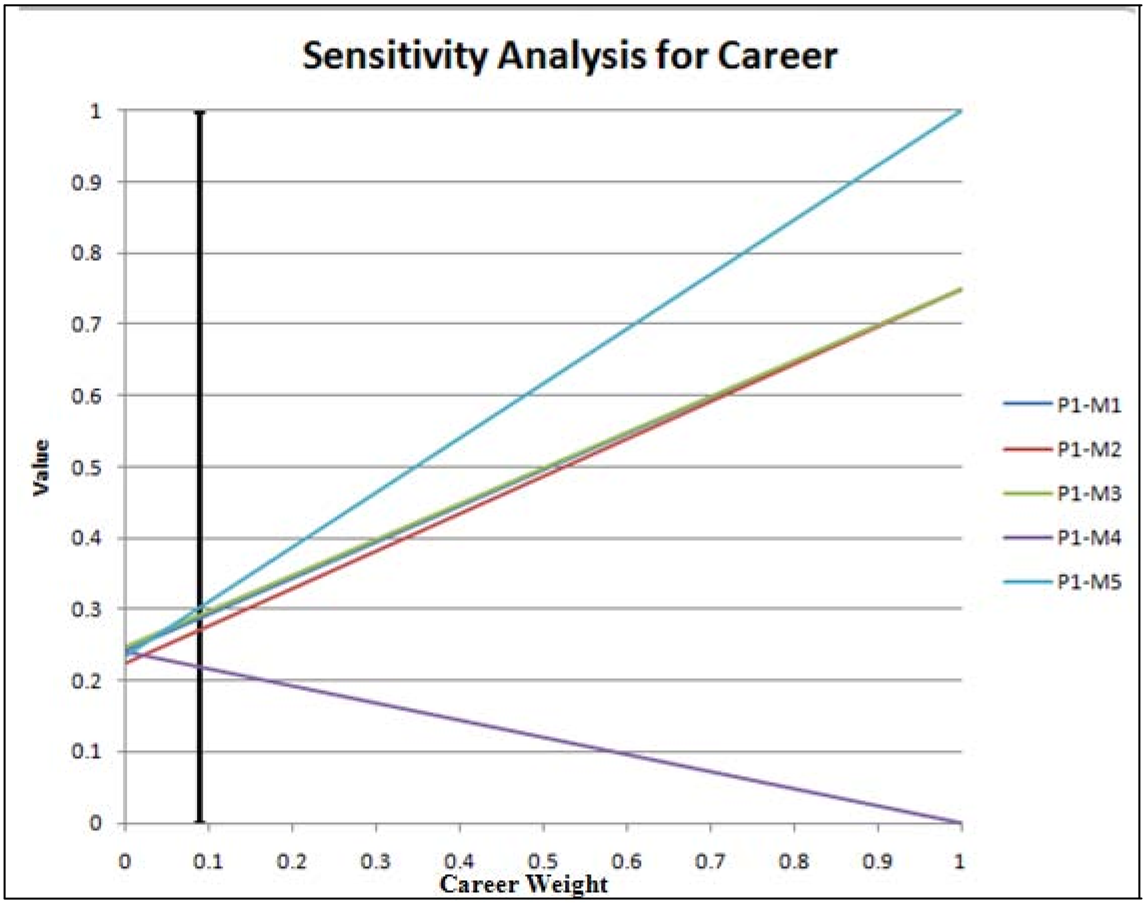


Figure 20: One Way Sensitivity Analysis for Career

Figure 20 shows the effects of changes on Career's weight. M-2 and M-4 are always the bottom two but the others are again hard to order. Finally, the DM accepted that Career is more important than Personal Need and model's order is acceptable in these kinds of situations. Nevertheless running sensitivity analysis is crucial when scores are so close.

The last problem in this part is the hardest for the DM to solve and decide on the order of alternatives because Currency, Wanted Readiness, Personal Need and Career inputs are all provided randomly.

Missions	Currency Left	Wanted Left	Personal Need	Career
M-1	88	9	2	1
M-2	89	58	3	0
M-3	90	32	2	1
M-4	91	4	3	0
M-5	92	9	5	0

Table 32: Inputs for Problem-5

DM's Order	Model's Order	Overall Scores From Model
M-4	M-4	0.397
M-1	M-1	0.335
M-5	M-5	0.313
M-2	M-2	0.306
M-3	M-3	0.218

Table 33: Solutions for Problem-5

According to the DM, the last three are obvious but deciding the first two rows needs some time. However, since M-4 has only four days in wanted readiness, the weekly schedule should contain this assignment for the purpose of the readiness value and the DM and model agreed in their orderings.

4.2.2 Comparing Assignments of Five Different Pilots

The other class of problems in the validation part creates alternative assignments that contain five different pilots and five available missions, respectively. This part aims to show more complicated problems and the solutions of them by two operators.

Pilots	Missions	Wanted Left	Yearly Flight	Yearly Presence
P-1	M-1	99	103	171
P-2	M-2	101	17	134
P-3	M-3	118	44	130
P-4	M-4	33	108	144
P-5	M-5	77	67	151

Table 34: Inputs for Problem-6

Table 34 shows the randomized inputs for the Wanted Readiness and Yearly Scheme evaluation measures. In this problem, the model compares these two measures according to the DM’s preferences and decides the order of the five assignments. Other needed inputs were kept constant for all matches. The following table introduces the results.

DM's Order	Model's Order	Overall Scores From Model
P2-M2	P2-M2	0.287
P4-M4	P4-M4	0.282
P3-M3	P3-M3	0.254
P5-M5	P5-M5	0.222
P1-M1	P1-M1	0.164

Table 35: Solutions for Problem-6

With respect to Table 35, both operators’ solutions are exactly the same. These identical results support validation of the model.

Pilots	Missions	Monthly Flight	Monthly Presence	Duty Total	Duty Max
P-1	M-1	0	17	14	15
P-2	M-2	2	12	3	15
P-3	M-3	1	6	4	15
P-4	M-4	4	7	15	15
P-5	M-5	9	2	12	15

Table 36: Inputs for Problem-7

Table 36 has the inputs for Problem-7 which tests the comparison between Monthly Scheme and Duty Equality. All inputs were acquired randomly in their limits and measures other than these two were assumed to be constant.

DM's Order	Model's Order	Overall Scores From Model
P3-M3	P3-M3	0.286
P1-M1	P4-M4	0.264
P4-M4	P1-M1	0.256
P2-M2	P2-M2	0.237
P5-M5	P5-M5	0.203

Table 37: Solutions for Problem-7

The model's solution is a little different than the DM's order but the scores of alternatives ordered differently are similar. When considering alternatives that are confusing to the DM, the DM did not have concern with monthly presence. However, the structure does use presences. Finally, the DM agreed with the structure and admitted that the order the model came up with is more logical based on the monthly presences. Because Pilot-4 has only seven days left this month to fly, he/she needs to fly more than Pilot-1 who has seventeen days left. Also, Pilot-4 has the maximum on duty numbers. Thus, from all aspects of DM's preferences, Pilot-4 should fly prior to Pilot-1. To sum up, VFT works and these situations prove just that. With the Value Focused Thinking method, the DM defines preferences as a structure first and then the structure solves the problem according to the DM's concerns. Flight scheduling in fighter squadrons is a huge problem and needs structured thinking with the help of a computer that can consider all entries thoroughly.

Pilots	Missions	Weekly Flight	Weekly Presence	Permission Requests	Past Percentage
P-1	M-1	3	1	0	1
P-2	M-2	0	2	0	0.33
P-3	M-3	2	1	1	0
P-4	M-4	0	1	0	0.25
P-5	M-5	2	3	0	0

Table 38: Inputs for Problem-8

Problem-8 seeks the validation for trade-offs between Weekly Scheme and Permission measures. Table 38 shows the inputs for this problem. The Permission Requests column tells about whether the respective pilot wants permission to not fly. The Past Percentage column calculates the percentage of permission requests positively answered by the commander.

DM's Order	Model's Order	Overall Scores From Model
P3-M3	P3-M3	0.297
P2-M2	P2-M2	0.286
P4-M4	P4-M4	0.285
P1-M1	P1-M1	0.276
P5-M5	P5-M5	0.268

Table 39: Solutions for Problem-8

Table 39 introduces the DM's and model's solutions for Problem-8. In terms of evaluating the trade-off between Weekly Scheme and Permission, there seems to be no difference among the two solutions.

Pilots	Missions	Yearly Flight	Monthly Flight	Weekly Flight	Daily Flight
P-1	M-1	46	5	3	0
P-2	M-2	70	9	2	0
P-3	M-3	31	3	0	0
P-4	M-4	54	5	3	0
P-5	M-5	7	5	1	0

Table 40: Inputs for Problem-9 Part-1

Pilots	Missions	Yearly Presence	Monthly Presence	Weekly Presence	Daily Presence
P-1	M-1	170	14	1	1
P-2	M-2	183	1	4	3
P-3	M-3	139	1	5	1
P-4	M-4	146	12	1	1
P-5	M-5	114	17	1	1

Table 41: Inputs for Problem-9 Part-2

Problem-9 is a challenging problem and examines the reactions of the model and the DM to the kind of problem that has a lot of variables to analyze. Inputs for the Frequency value were found with the Excel RandBetween function and other variables were assumed to be constant. In this problem, the DM and model have to compare priorities between the Yearly Scheme, Monthly Scheme, Weekly Wanted and Daily Wanted evaluation measures and decide the order of five alternatives randomly constructed. Table 40 states the number of flights as yearly, monthly, weekly and daily for five pilots. Furthermore, Table 41 reveals the available presences for these pilots in this year, month, week and day.

DM's Order	Model's Order	Overall Scores From Model
P5-M5	P3-M3	0.387
P3-M3	P5-M5	0.371
P4-M4	P4-M4	0.266
P1-M1	P1-M1	0.260
P2-M2	P2-M2	0.187

Table 42: Solutions for Problem-9

According to the solutions shown in Table 42, there is a difference between the DM's and the model's orders. The DM wants to schedule Pilot-5 prior to Pilot-3 contrary to the model. Before changing the decision model we first review the structure.

		Weights			
		0.170	0.097	0.020	0.039
Pilots	Missions	Yearly Scheme	Monthly Scheme	Weekly Scheme	Daily Scheme
P-3	M-3	0.640	1.00	0.60	1
P-5	M-5	0.991	0.18	1.00	1

Table 43: Scores for Frequency Evaluation Measures in Problem-9

In terms of daily schemes, there is no difference between pilots as can be seen from Table 43. Considering weights, the most important measure is Yearly Scheme and then Monthly Scheme. The differences between scores show that the monthly flight count of Pilot-3 needs to be boosted immediately. Also, Pilot-3 has only one day in that month to fly but Pilot-5 has seventeen available days, so he/she can accomplish the monthly goal more easily. After the explanation, the DM did not want to change the weights and kept the model's scores and rankings.

Pilots	Missions	Currency Left	Wanted Left	Yearly Max	Monthly Max
P-1	M-1	55	0	83	7
P-2	M-2	58	7	83	7
P-3	M-3	81	30	83	7
P-4	M-4	71	40	83	7
P-5	M-5	73	51	83	7

Table 44: Inputs for Problem-10 Part-1

Pilots	Missions	Yearly Flight	Monthly Flight	Weekly Flight	Daily Flight
P-1	M-1	77	0	1	0
P-2	M-2	78	6	0	0
P-3	M-3	8	3	3	0
P-4	M-4	24	7	1	0
P-5	M-5	83	3	1	0

Table 45: Inputs for Problem-10 Part-2

Pilots	Missions	Yearly Presence	Monthly Presence	Weekly Presence	Daily Presence
P-1	M-1	161	17	2	3
P-2	M-2	115	19	5	2
P-3	M-3	145	18	4	2
P-4	M-4	116	11	4	3
P-5	M-5	113	15	3	3

Table 46: Inputs for Problem-10 Part-3

As seen on Table 44, Table 45 and Table 46, the last validation problem requires the comparison of the preferences on the Readiness and Frequency values and also two measures of the Motivation value. It takes into account eight out of the twelve measures

and assumes the other four measures are unchanged. The following table shows the results.

DM's Order	Model's Order	Overall Scores From Model
P3-M3	P3-M3	0.358
P4-M4	P4-M4	0.323
P1-M1	P1-M1	0.308
P2-M2	P2-M2	0.288
P5-M5	P5-M5	0.219

Table 47: Solutions for Problem-10

According to the orders shown in Table 47, there is no difference between the solutions. The model seems accurate even in difficult and complicated problems such as Problem-10 which has eight variables.

4.3 Summary

This chapter discussed verification and validation of the research model. The first part verified the calculations in this research and the software program named Hierarchy Builder 2.0 which was used to build the VFT model (Weir J. , 2008). The second part validated the model via comparing solutions created by the DM and the research model in order to solve sample assignment problems. The last chapter presents conclusions and recommendations about this research.

5. CONCLUSIONS

In this chapter, the summary of research, conclusions and future research recommendations are presented.

5.1 Summary of the Research

Chapter 1 starts with defining the general problem and continues by stating the specific problem of this research. The general problem is the assignment problem which is one of the main problems in Operations Research. The specific problem is flight scheduling in fighter squadrons. After revealing the problem, the scope of the research is mentioned as the first two steps of the process of modeling the scheduler. Considering the scope of this research, an evaluation model using VFT is built and a helpful program is established to aid the scheduler in manually building schedules.

The next chapter of this research reviews recent research about both the general problem and the specific problem. After reviewing previous works, Chapter 2 tries to make clear why the assignment problem or flight scheduling problem in fighter squadrons can be approached using decision analysis methods. Thus, decision analysis methods are discussed in this chapter. The last part of Chapter 2 reviews the ten step method of VFT which is implemented in Chapter 3.

Chapter 3 begins with general information about flight scheduling in fighter squadrons. The first part of this chapter defines inputs and outputs of the specific problem of this research. The second part of Chapter 3 contains the first seven steps of VFT.

Verification and validation of the decision model created with the help of the DM's preferences are introduced in Chapter 4. A sample alternative assignment is evaluated manually and by the model. Furthermore, ten groups of alternatives are

evaluated and ordered by the DM and the decision model in order to compare the solutions and validate the model.

In the next part of this chapter, analysis results are explained and objectives of the research and accomplishments are discussed. Finally, future recommendations are stated in the last part of this chapter.

5.2 Conclusions

Verification of the model as discussed in Chapter 4 has two parts. The first part considers the Hierarchy Builder 2.0 software program. In order to see whether the program is accurate, one sample calculation for a score of an evaluation measure was made by hand to compare results with the model's results. Nine inputs were evaluated and compared with model's results and the average difference between scores was too small and only changes the scores in the fifth decimal place. As far as this research's specific problem is concerned, this type of accuracy is fine and the model is accepted as verified. The second part for verification focuses on the changes of this research to the software program for the purpose of accelerating it. Embellishments made by this research include evaluating the scores of all evaluation measures concerning assignments immediately while entering the needed inputs of the alternatives. Besides this, the overall scores are calculated immediately for all alternatives by these additions. Ten random alternatives were created and evaluated by Hierarchy Builder 2.0 and by this research's model. Because the software program uses big numbers to simulate infinity, there were minor differences on some evaluation measure scores. When using linear functions as SDVF of an evaluation measure, the program gives an approximate value as an output. However, the research's model uses the ratios as outputs directly. That means it is not

approximating infinity by big numbers as the software does and gives exact values for the corresponding evaluation measures. Finally, the average difference between overall scores was calculated. It is not a significant number with respect to this research's objectives.

In order to validate the decision model, ten sample groups of five alternative assignments are created by randomizing the needed inputs. After creating the groups of alternatives, the DM ordered them in accordance with his preferences. The value model ordered the same groups of sample alternatives. Then the validation part continues with comparing the results and commenting on the differences. In general, there were only four different ordered groups out of the ten groups and these differences were based on only two assignments in these different ordered groups. Analyzing the differences, some important findings are discussed here. The first reason that causes variation between the two orderings is the problem of the DM's calibration. The decision model was built with the inputs of the DM and the decision process was structured for future problems. However, the DM still thinks in an unstructured way. He thinks about one evaluation measure at a time or can think about two measures and decides only using them. Because the DM does not think in a structured way, this research aims to structure the DM's values and preferences. The validation part shows that the DM's weakness continues. We need to calibrate the DM first and then solicit him again after this procedure. For almost all sample groups, this process was applied and the DM accepted the solution of the model instead of his solution. So this finding validates the model due to the objectives of this research. The second important finding of the validation part was seen after the different ordered alternatives' scores are examined. The differences between scores were

too small and thus the DM could choose any of them after looking at the big picture the model provides. Sensitivity analysis was run in order to make the DM think about the weights. However, the DM did not want to change the weights because the needed range of change was not logical according to his views. This finding also validates the model because this model was created to show a big picture and to help the DM to see the priorities between assignments. It is not for making a decision for the best assignment. After getting the big picture, the DM can choose any alternatives by his experience and make the schedule. The other important result of validation was about time. Some of the validation samples created kept almost ten variables constant but some of them used more than five variables and entered random inputs. The DM started to consume a large amount of time thinking about those problems that have more than four variables. Even with two variables, he doesn't have structured thinking, so we cannot expect accuracy on bigger problems. Nevertheless, the model does not consume much time to get the evaluation of needed alternatives or order them. This fact proves the model useful with regard to one of this research's objectives defined in Chapter 1. This goal is to reduce the total time it takes a scheduler to do his/her job. Using the model instead of starting from scratch is introducing an invaluable time advantage.

In Chapter 1, four objectives are stated along with the research question. The first objective is providing simplicity, flexibility and structured thinking to the assignment problem. Using user friendly software programs such as Excel and Hierarchy Builder 2.0 simplifies the work the DM does. He/she can easily add some steps to this model to make a more robust model or remove some parts from the model to get rid of unnecessary or old measures. The DM can easily change weights or values because the programs are

flexible. Furthermore, VFT starts with defining objectives and values; then it continues with structuring a decision model to recommend decisions according to defined preferences.

The second objective achieved is showing a big picture of the current state of the problem to the decision makers. After the scoring alternatives step, deterministic analysis and sensitivity analysis help build the big picture. The main spreadsheet for the overall score gives the biggest picture for the problem. However, other spreadsheets are obtained by using filters in Excel in order to see a specific pilot's current status or a specific mission's assignment scores. The DM can see all matches at the same time or he/she can filter the assignments and can acquire necessary assignments to be able to think about them thoroughly. He/she can choose several matches and then run a sensitivity analysis to see the effects of weights. These abilities prove that the second objective was achieved.

The next objective is changing subjective decisions to objective ones. As is written in Chapter 3, the flight scheduling process in fighter squadrons is not objective. There are several decision makers and subject matter experts that have an effect on schedules. They have different objectives and preferences and the Air Force also has important objectives about flying missions. The VFT method constructs an objective model and the decisions made with the help of this model will be repeatable and consistent. The DM may decide with bias but the model does not. The DMs and the SMEs can answer the same problem differently but the model will be consistent and solve the same problem and find the same solution every time.

The last objective mentioned in Chapter 1 is to reduce the total time it takes a scheduler to do their job. The model certainly decreases the time consumed because it

combines all evaluation measures into only one overall score. Hence, the DM can use the overall scores to consider the assignments' values and decide in less time. The model not only decreases the amount of time the scheduler consumes but also increases the number of variables the scheduler takes into account. The DM considers only two or three of the evaluation measures even if there are more than three measures. Using the decision model, a large number of variables can be evaluated in a short time and concisely. Furthermore, the DM chooses several important assignments to start with because the problem has approximately 1500 assignment alternatives. He/she thinks like that because considering all of the alternatives is not logical due to time limits. Nevertheless, a computer model can do this work in a small amount of time and give the values for 1500 assignments in almost one second. The only job for the SME is to create a feasible sequence using these scores. Finally, this model reduces the total time for the scheduling process and makes it more robust because it does not skip any alternative.

5.3 Future Recommendations

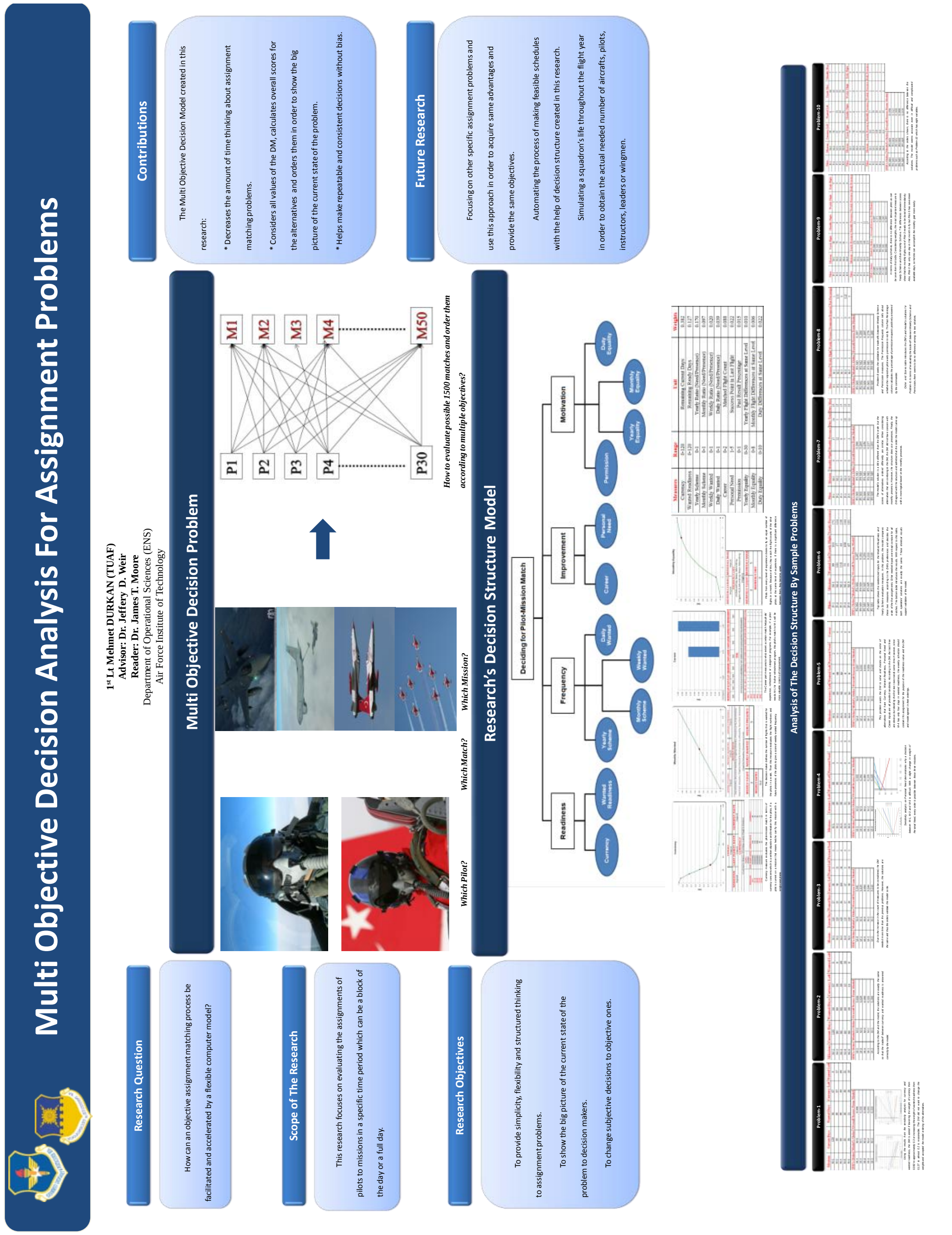
Future researchers should focus on other specific assignment problems and use this approach in order to acquire same advantages and provide the same objectives. The VFT method can be used in all types of assignment problems to construct a decision model and help DMs save time.

In this research, flight scheduling in fighter squadrons is held as an assignment problem to show how to approach the assignment problem with a different method. As described in Chapter 1, modeling the scheduler has three steps and this research tries to solve the first two steps. It builds the decision analysis model for evaluating the alternatives and makes spreadsheets to aid the scheduler in manually building schedules.

The third step is left for future research. This step will automate the process of pilot-mission assignment with the help of defined values and objectives. This step can be approached by a heuristic method like GRASP or a math model. The advantage of a heuristic method is that it is less time consuming but it does not guarantee the best solution. The Math method can conclude with the best results, but it may take a long time which is so valuable for pilots.

Future research may also want to simulate a squadron’s life throughout the flight year. This simulation research can use the decision model created by this research in order to obtain evaluation of the assignment alternatives, and it can use random numbers of pilots or random numbers of aircrafts to get a good solution. Furthermore, this simulation research could use different numbers of instructors or leaders to see how many of them are actually needed for fighter squadrons. These numbers can be an input for Air Force aircraft projects and personal assignments.

APPENDIX A: QUAD CHART



APPENDIX B: VALUE FUNCTIONS AND FORMULAS

In this section twelve value functions, related formulas and needed data will be shown.

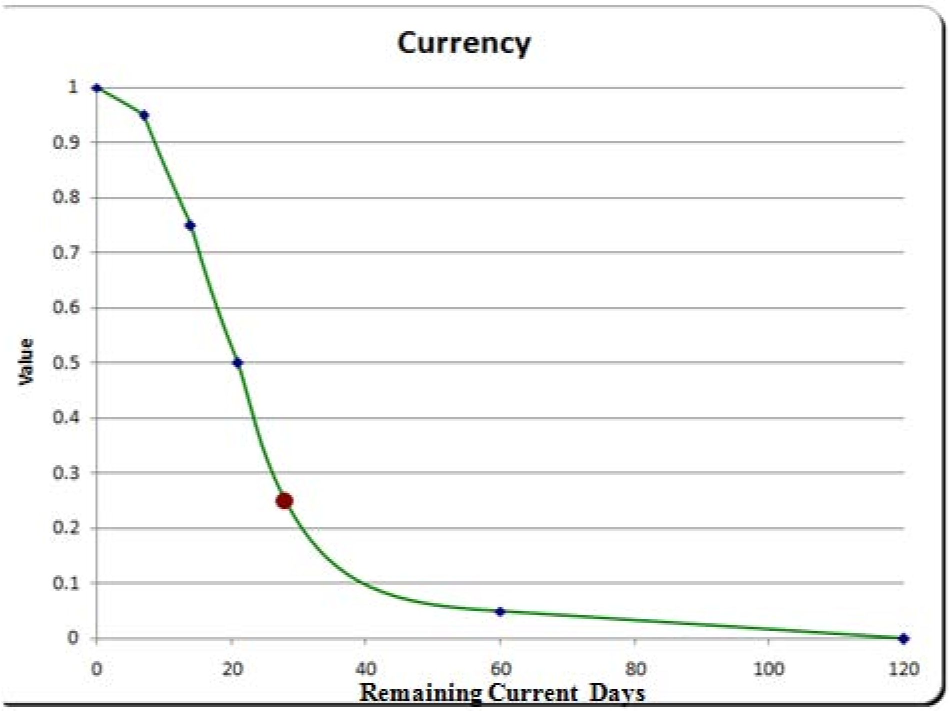


Figure 21: SDVF for Currency

	TODAY		
	1/3/2011		
MISSIONS	LAST FLIGHT DATE	CURRENT DAYS	CURRENCY
M-1	12/13/2010	120	99
M-13	12/14/2010	110	90
M-23	12/15/2010	100	81
M-42	12/16/2010	90	72
M-50	12/17/2010	75	58

Table 48: Spreadsheet for Needed Data of Currency Scores Calculations

	TODAY	
	Input	
MISSIONS	LAST FLIGHT DATE	CURRENT DAYS
Input	Input	Input
CURRENCY		
Current Days-(Today-Last Flight Date)		

Table 49: Formulas and Descriptions of Entries for Currency Spreadsheet

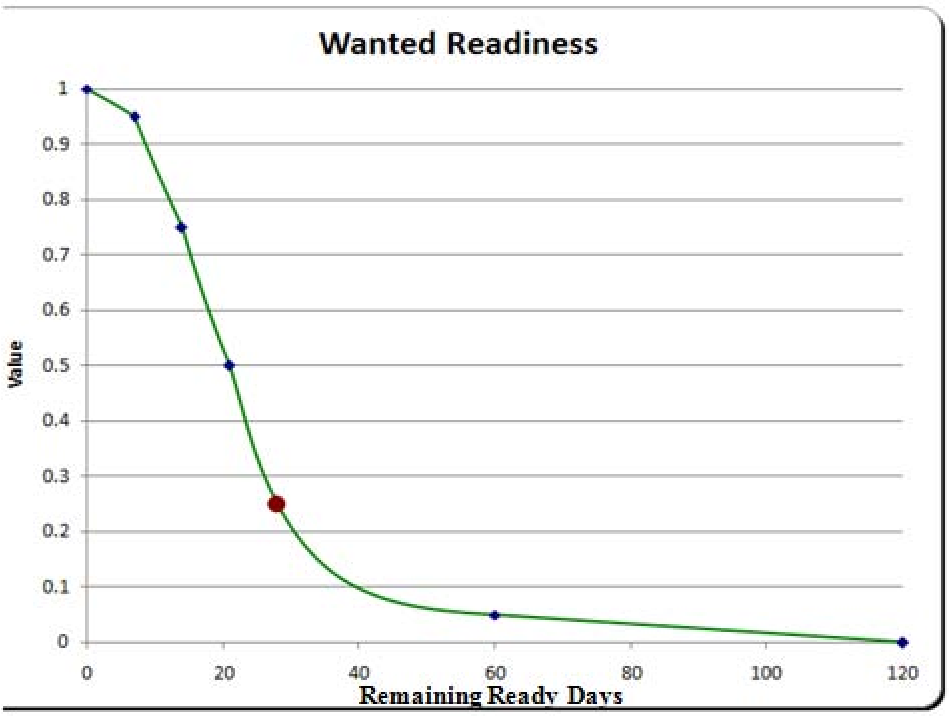


Figure 22: SDVF for Wanted Readiness

	TODAY		
	1/3/2011		
MISSIONS	LAST FLIGHT DATE	WANTED DAYS	WANTED
M-1	12/13/2010	100	79
M-13	12/14/2010	90	70
M-23	12/15/2010	80	61
M-42	12/16/2010	70	52
M-50	12/17/2010	60	43

Table 50: Spreadsheet for Needed Data of Wanted Readiness Scores Calculations

	TODAY	
	Input	
MISSIONS	LAST FLIGHT DATE	WANTED DAYS
Input	Input	Input
WANTED		
Wanted Days-(Today-Last Flight Date)		

Table 51: Formulas and Descriptions of Entries for Wanted Readiness

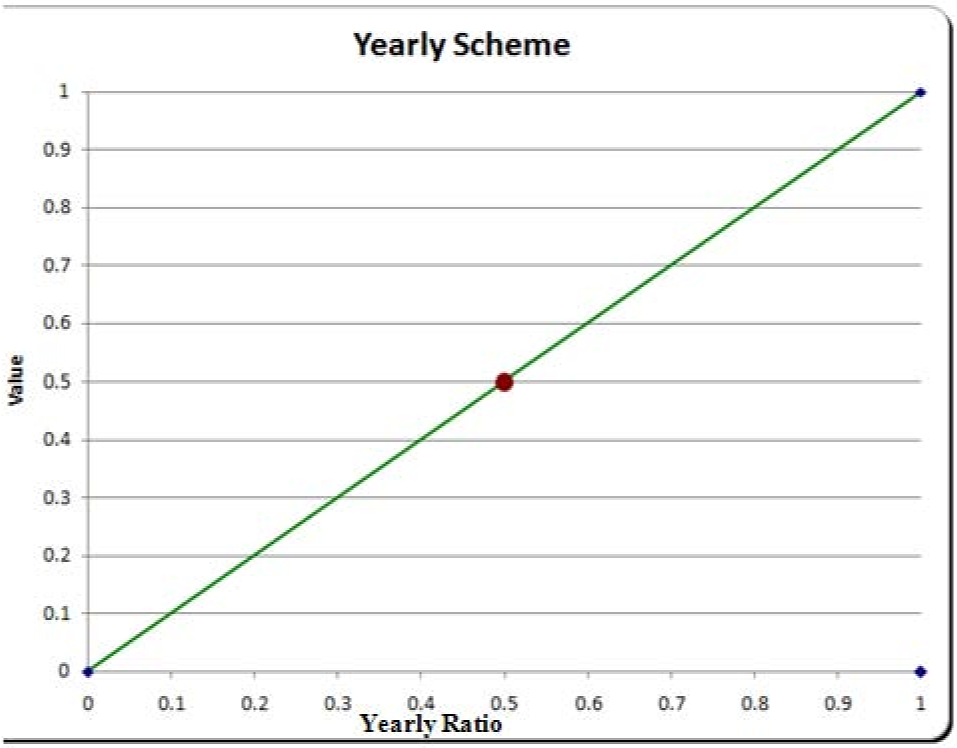


Figure 23: SDVF for Yearly Scheme

YEARLY FLIGHT	YEARLY SCHEME	YEARLY PRESENCE
19	120	173
YEARLY RATIO		
0.583815029		

Table 52: Spreadsheet for Needed Data of Yearly Scheme Scores Calculations

YEARLY FLIGHT	YEARLY SCHEME	YEARLY PRESENCE
Input	Input	Input
YEARLY RATIO		
IF((Yearly Scheme-Yearly Flight)/Yearly Presence>0,IF((Yearly Scheme-Yearly Flight)/Yearly Presence<1,(Yearly Scheme-Yearly Flight)/Yearly Presence,1),0)		

Table 53: Formulas and Descriptions of Entries for Yearly Scheme

Figure 24: SDVF for Monthly Scheme

MONTHLY FLIGHT	MONTHLY SCHEME	MONTHLY PRESENCE
3	8	21
MONTHLY RATIO		
0.238095238		

Table 54: Spreadsheet for Needed Data of Monthly Scheme Scores Calculations

MONTHLY FLIGHT	MONTHLY SCHEME	MONTHLY PRESENCE
Input	Input	Input
MONTHLY RATIO		
IF((Monthly Scheme-Monthly Flight)/Monthly Presence>0,IF((Monthly Scheme-Monthly Flight)/Monthly Presence<1,(Monthly Scheme-Monthly Flight)/Monthly Presence,1),0)		

Table 55: Formulas and Descriptions of Entries for Monthly Scheme

Figure 25: SDVF for Weekly Wanted

WEEKLY FLIGHT	WEEKLY WANTED	WEEKLY PRESENCE
2	3	5
WEEKLY RATIO		
0.2		

Table 56: Spreadsheet for Needed Data of Weekly Wanted Scores Calculations

WEEKLY FLIGHT	WEEKLY WANTED	WEEKLY PRESENCE
Input	Input	Input
WEEKLY RATIO		
IF((Weekly Wanted-Weekly Flight)/Weekly Presence>0,IF((Weekly Wanted-Weekly Flight)/Weekly Presence<1,(Weekly Wanted-Weekly Flight)/Weekly Presence,1),0)		

Table 57: Formulas and Descriptions of Entries for Weekly Wanted

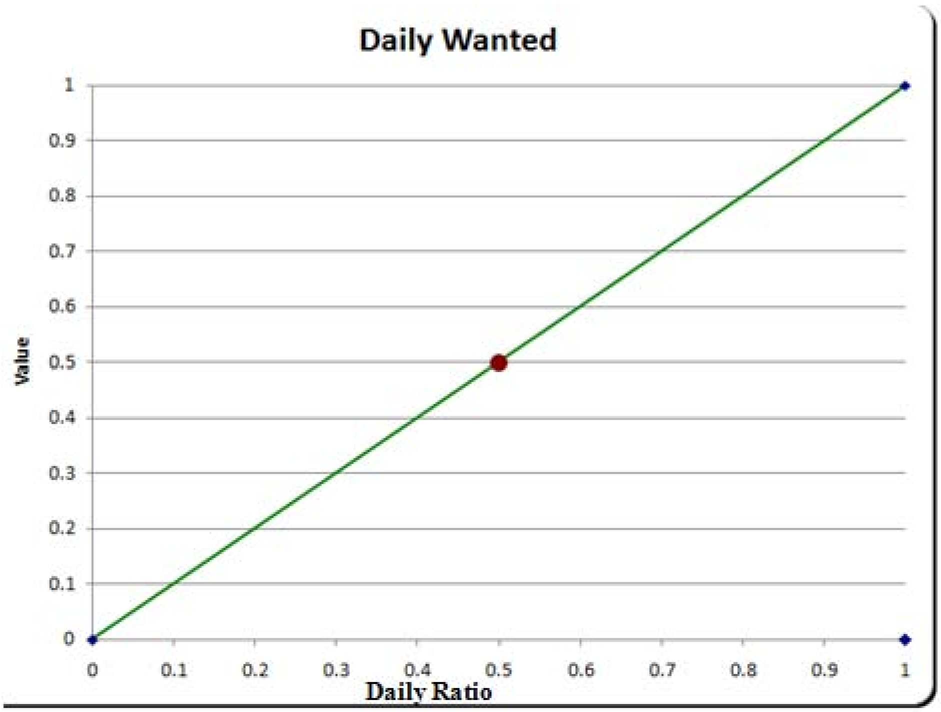


Figure 26: SDVF for Daily Wanted

DAILY FLIGHT	DAILY WANTED	DAILY PRESENCE
0	1	3
DAILY RATIO		
0.333333333		

Table 58: Spreadsheet for Needed Data of Daily Wanted Scores Calculations

DAILY FLIGHT	DAILY WANTED	DAILY PRESENCE
Input	Input	Input
DAILY RATIO		
IF((Daily Wanted-Daily Flight)/Daily Presence>0,IF((Daily Wanted-Daily Flight)/Daily Presence<1,(Daily Wanted-Daily Flight)/Daily Presence,1),0)		

Table 59: Formulas and Descriptions of Entries for Daily Wanted

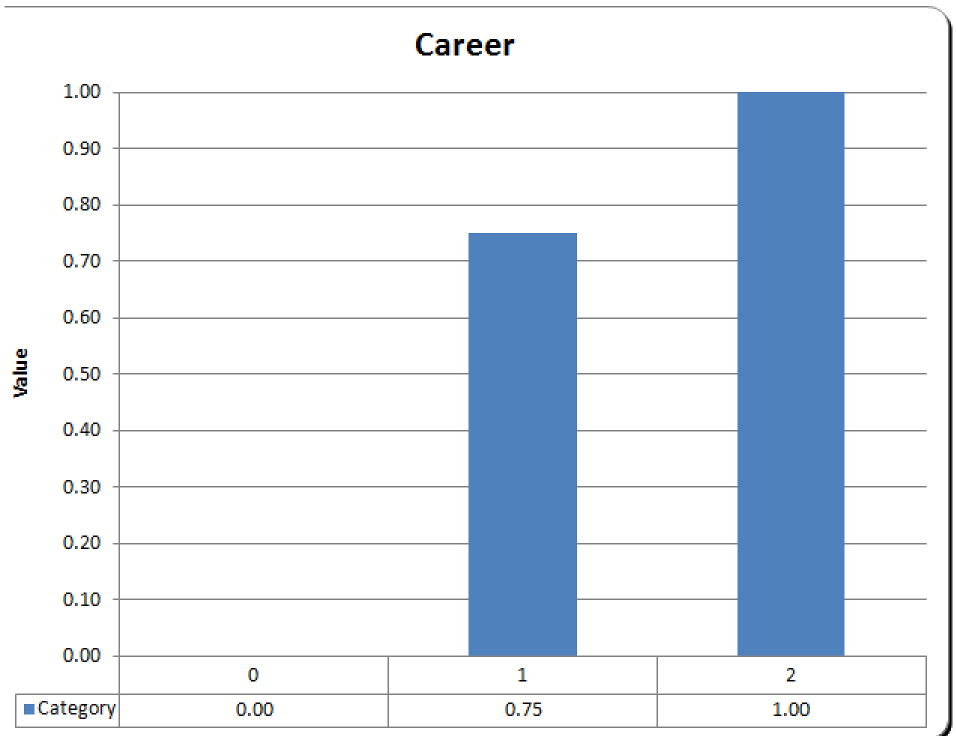


Figure 27: SDVF for Career

MISSIONS	CAT-III	CAT-II	CAT-I	BEGINNER	2 SHIP LEADER	4 SHIP LEADER	INSTRUCTOR	REFRESHMENT	TOTAL
M-1	0	0	0	0	0	0	0	0	0
M-13	1	0	0	1	0	0	0	0	2
M-23	0	0	0	1	0	0	0	0	1
M-42	0	1	0	0	1	0	0	0	2
M-50	0	0	0	0	0	0	1	0	1

Table 60: Spreadsheet for Needed Data of Career Scores Calculations

MISSIONS	CAT-III	CAT-II	CAT-I	BEGINNER	2 SHIP LEADER	4 SHIP LEADER	INSTRUCTOR	REFRESHMENT
Input	Input	Input	Input	Input	Input	Input	Input	Input
TOTAL								
(CAT-III)+(CAT-II)+(CAT-I)+(BEGINNER)+(2 SHIP LEADER)+(4 SHIP LEADER)+(INSTRUCTOR)+(REFRESHMENT)								

Table 61: Formulas and Descriptions of Entries for Career

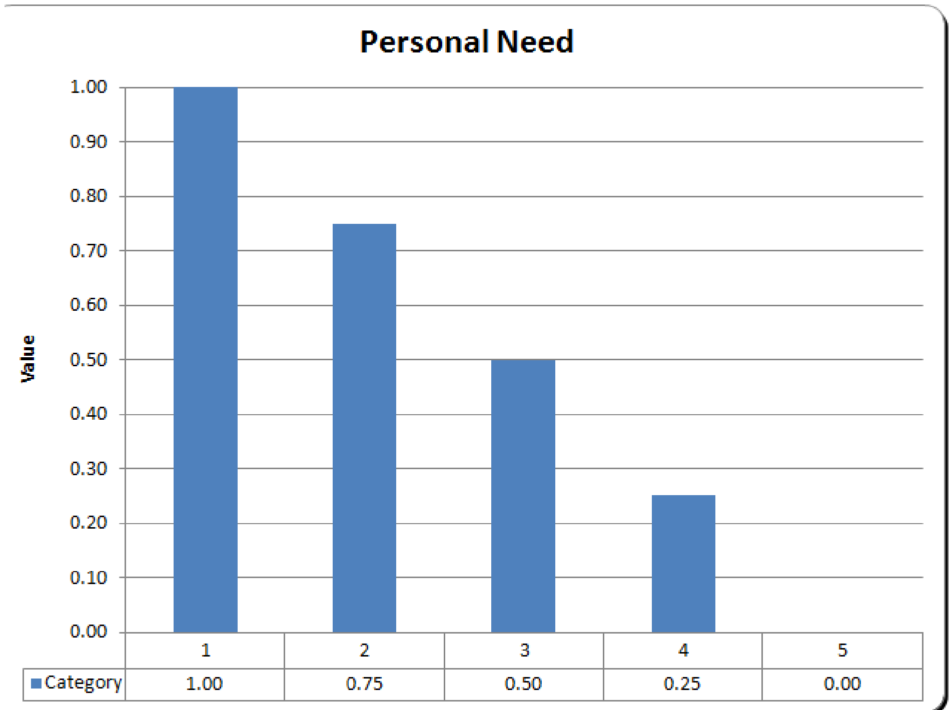


Figure 28: SDVF for Personal Need

MISSIONS	PERSONAL
M-1	5
M-13	4
M-23	3
M-42	2
M-50	1

Table 62: Spreadsheet for Needed Data of Personal Need Scores Calculations

MISSIONS	PERSONAL
Input	Input
Input	Input
Input	Input
Input	Input
Input	Input

Table 63: Formulas and Descriptions of Entries for Personal Need

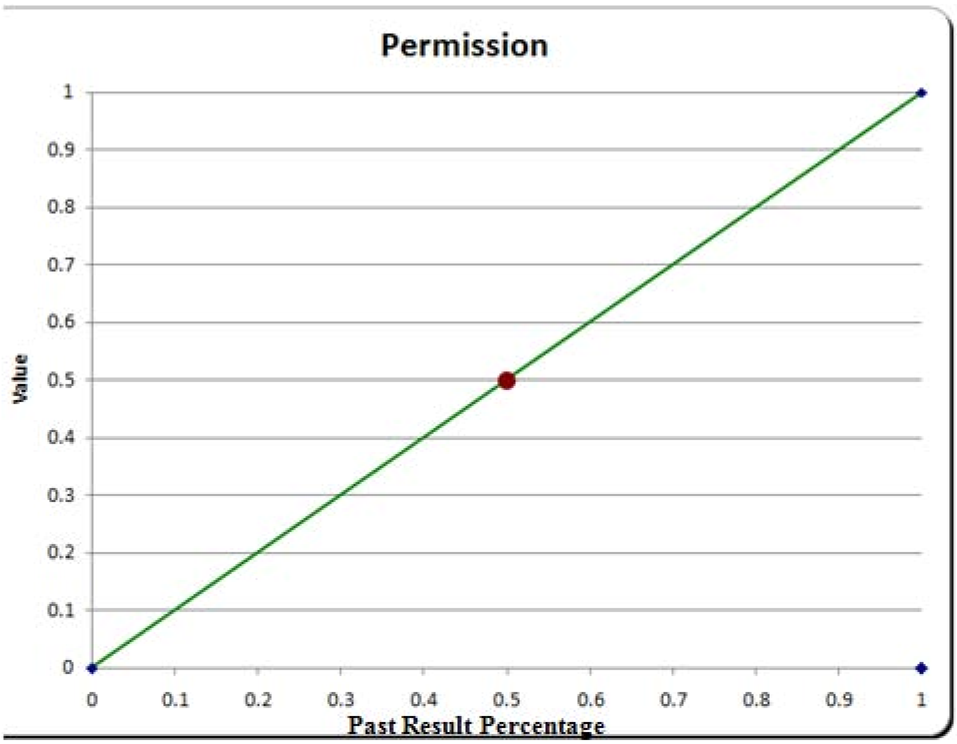


Figure 29: SDVF for Permission

WANT TO FLY?	PAST REQUESTS	PAST RESULTS	PAST PERCENTAGE
0	5	4	0.8
PERMISSION			
0.8			

Table 64: Spreadsheet for Needed Data of Permission Scores Calculations

WANT TO FLY?	PAST REQUESTS	PAST RESULTS	PAST PERCENTAGE
Input	Input	Input	Past Results/Past Requests
PERMISSION			
IF(Want to Fly=0,Past Percentage,1)			

Table 65: Formulas and Descriptions of Entries for Permission

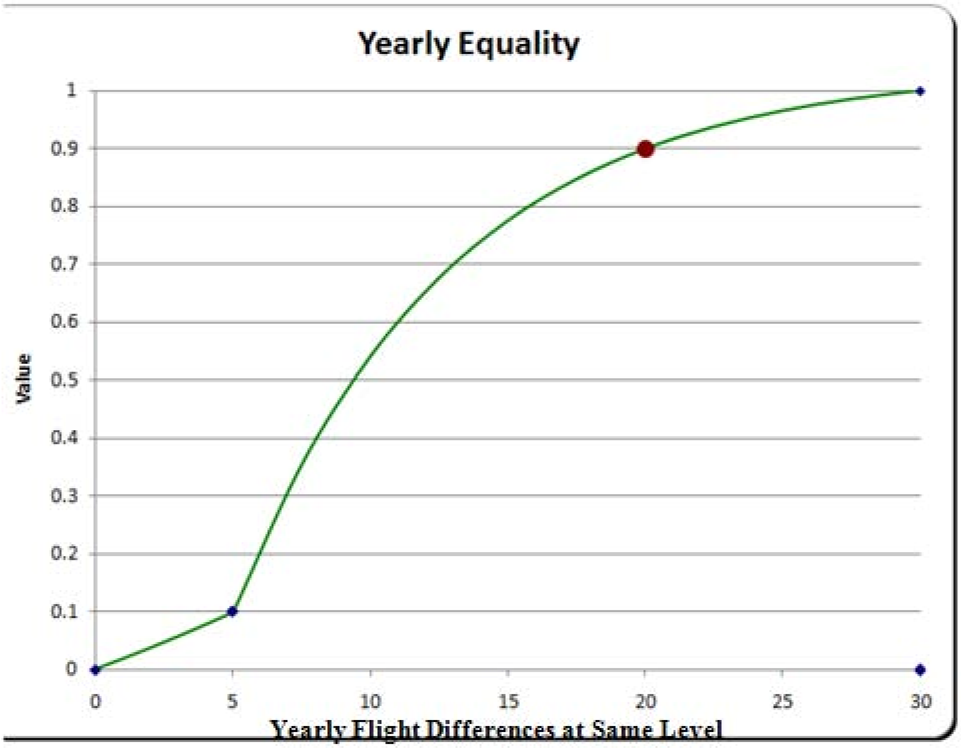


Figure 30: SDVF for Yearly Equality

YEARLY FLIGHT	YEARLY MAX
19	35
YEARLY DIFF	
16	

Table 66: Spreadsheet for Needed Data of Yearly Equality Scores Calculations

YEARLY FLIGHT	YEARLY MAX
Input	Input
YEARLY DIFF	
IF(Yearly Max-Yearly Flight>30,30,Yearly Max-Yearly Flight)	

Table 67: Formulas and Descriptions of Entries for Yearly Equality

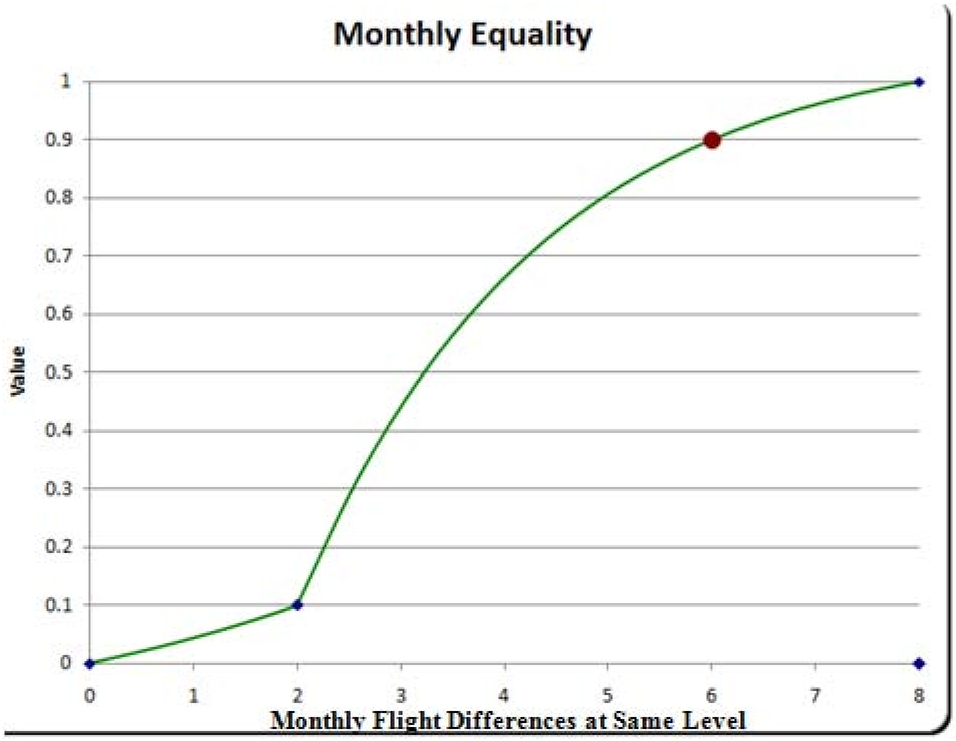


Figure 31: SDVF for Monthly Equality

MONTHLY FLIGHT	MONTHLY MAX
3	5
MONTHLY DIFF	
2	

Table 68: Spreadsheet for Needed Data of Monthly Equality Scores Calculations

MONTHLY FLIGHT	MONTHLY MAX
Input	Input
MONTHLY DIFF	
IF(Monthly Max-Monthly Flight>8,8,Monthly Max-Monthly Flight)	

Table 69: Formulas and Descriptions of Entries for Monthly Equality

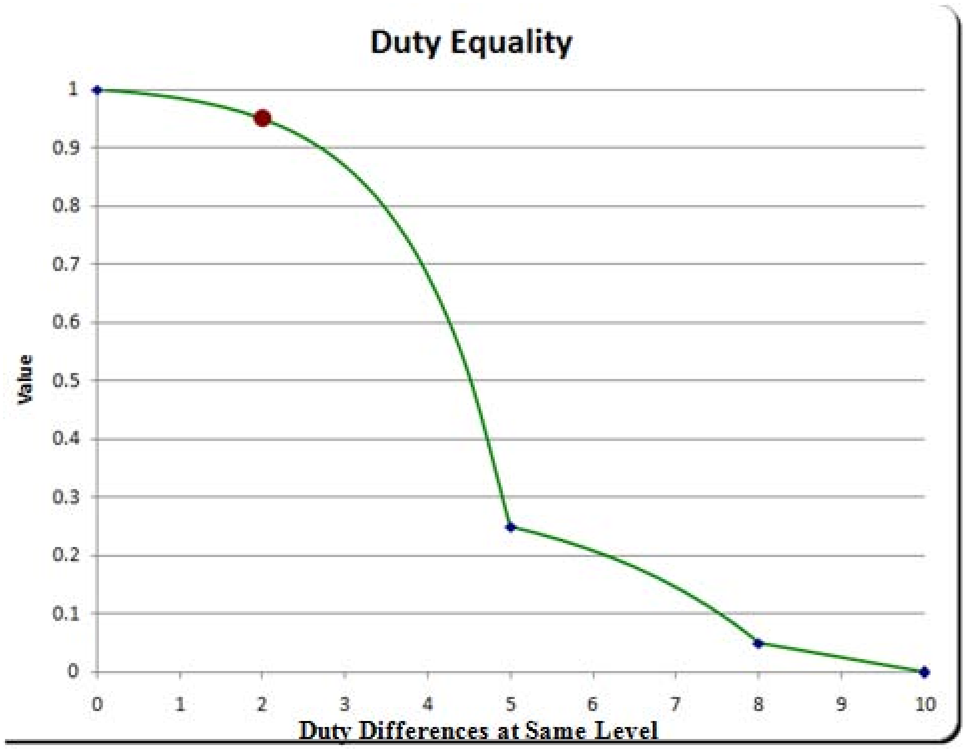


Figure 32: SDVF for Duty Equality

DUTY 1	DUTY 2	TOTAL	TOTAL MAX
1	2	3	5
DIFFERENCE			
2			

Table 70: Spreadsheet for Needed Data of Duty Equality Scores Calculations

DUTY 1	DUTY 2	TOTAL	TOTAL MAX
Input	Input	Duty1+Duty2	Input
DIFFERENCE			
IF(Total Max-Total>10,10,Total Max-Total)			

Table 71: Formulas and Descriptions of Entries for Duty Equality

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Vita

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14. ABSTRACT

One of the most common problems in Operations Research is the assignment problem. It deals with the optimization of a decision makers' goal by matching objects in one group (jobs) with objects in another (machines). Flight scheduling in fighter squadrons is a hard and complicated problem which comes with a dynamic environment and multiple decision makers and goals. Using pilots as machines and missions to be flown as jobs, the fighter squadron flight scheduling problem can be solved like an assignment problem with multiple goals. This research develops a new way to solve the multi-objective assignment problem and demonstrates this new approach using the fighter squadron flight scheduling problem as an example.

In this research, the Value Focused Thinking method is applied to build a decision analysis model to help decision makers in fighter squadrons evaluate the mission-pilot matches. The decision model built with the help of experienced schedulers is used not only for evaluating matches but also for ordering assignments to see priorities. To verify and validate this model, ten groups of alternatives were randomly created and evaluated by the model and the decision maker. The results from this analysis show that the decision model is valid and proved to be helpful and accelerated the assignment matching process.

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